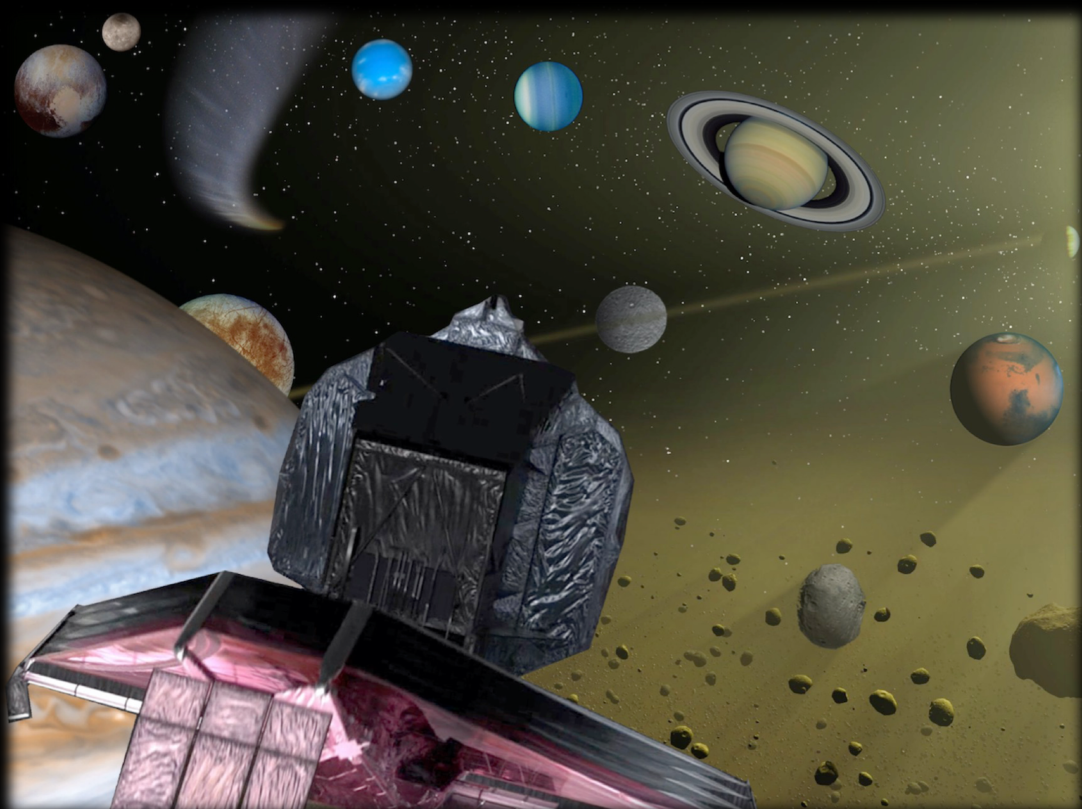
Solar System Science with JWST

Guaranteed Time Observations and Early Release Science

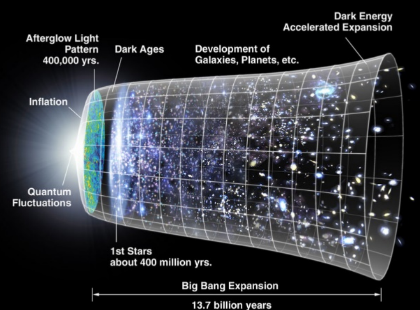


Heidi Hammel
JWST Interdisciplinary Scientist
for Solar System Observations
AURA, Washington, DC

Stefanie Milam
JWST Deputy Project Scientist
for Planetary Science
GSFC, Greenbelt, MD

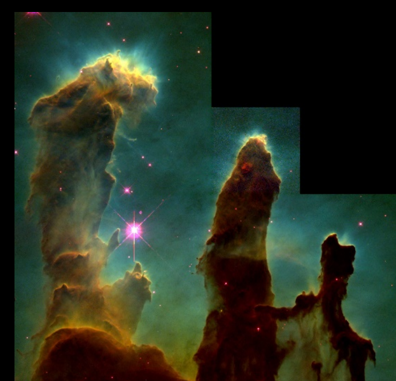
JWST Science Themes

First Light & Reionization

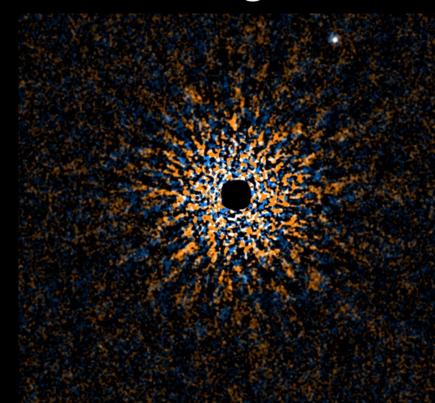


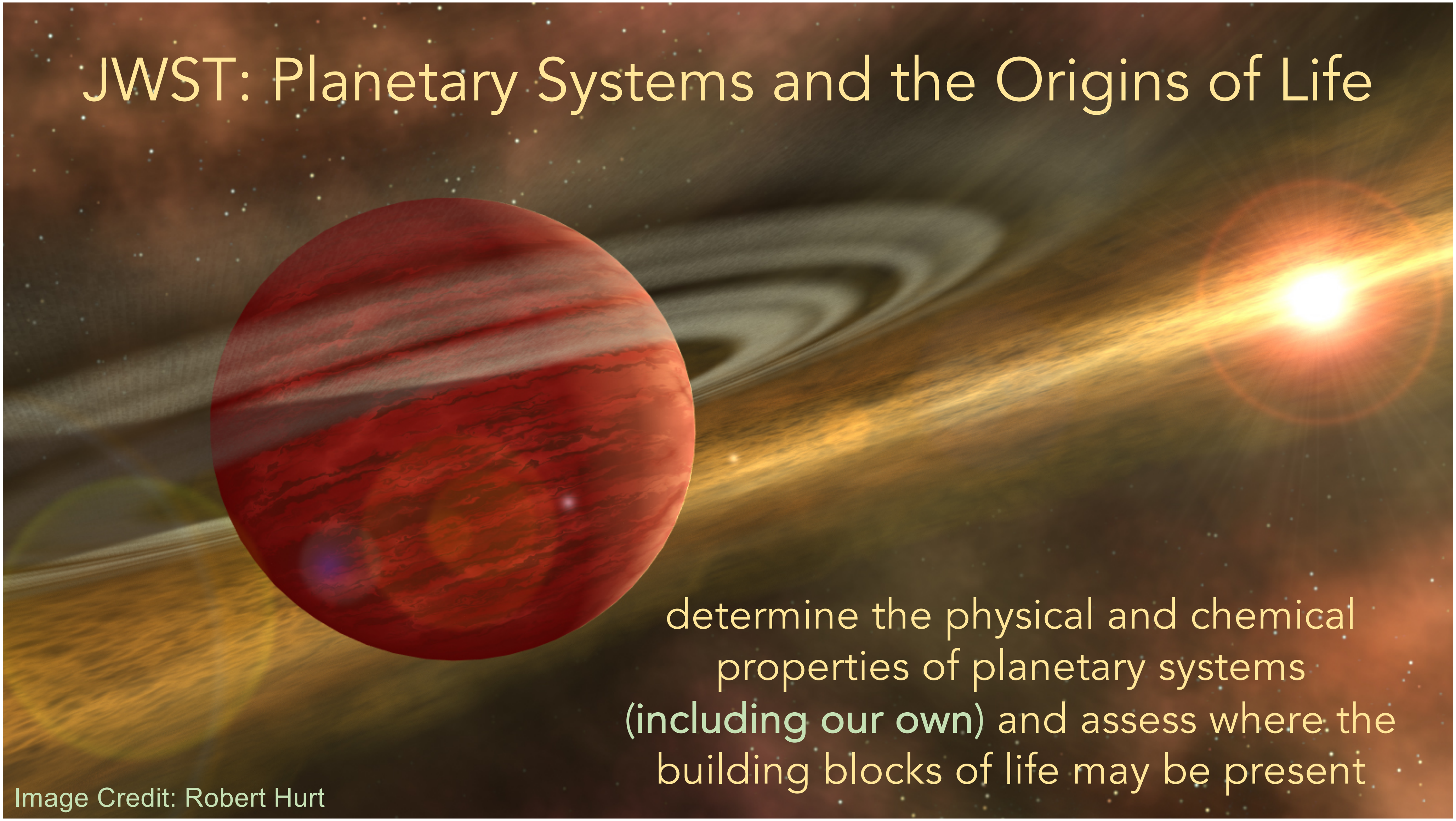
Assembly of Galaxies

Birth of Stars and Protoplanetary Systems

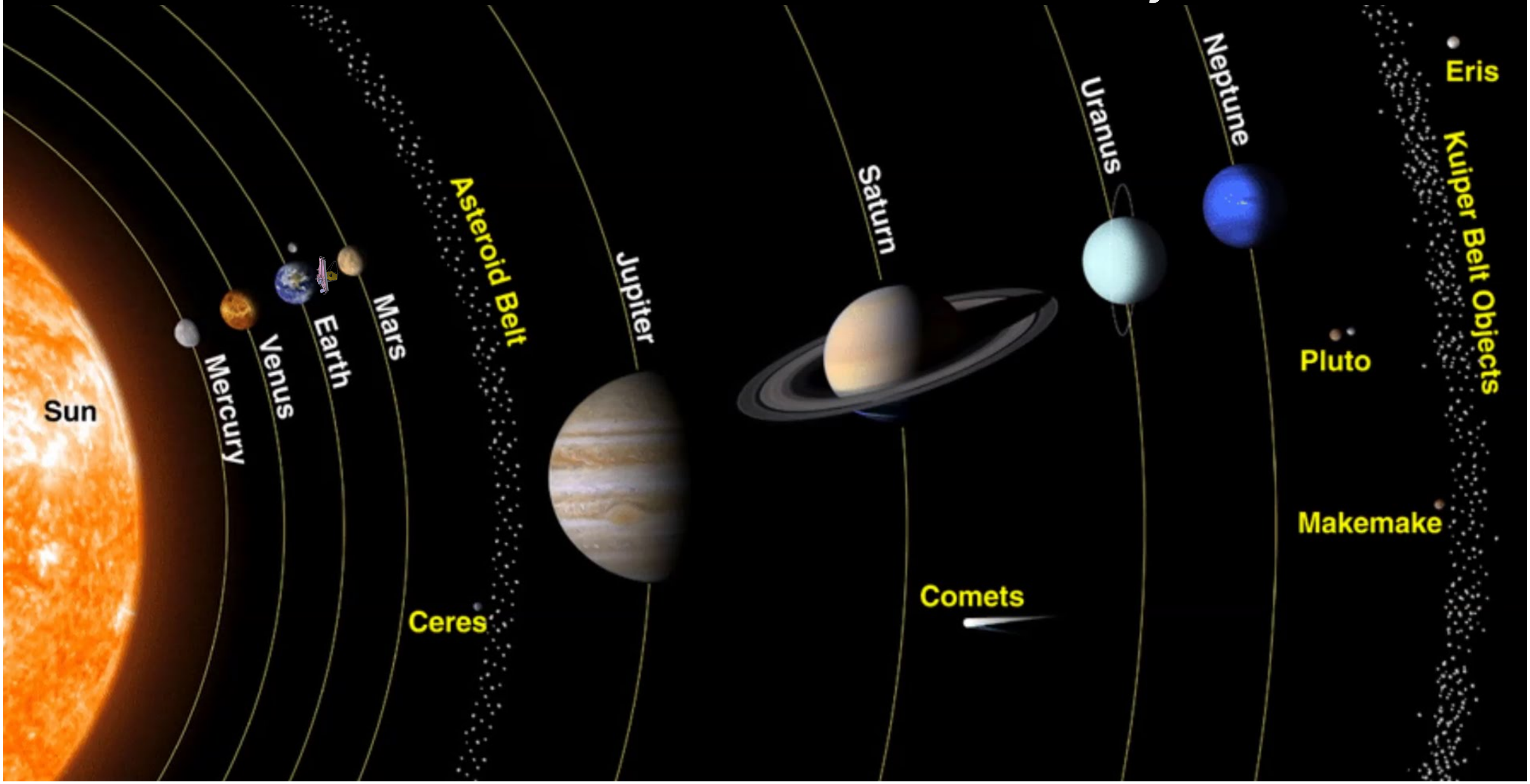


Planetary Systems and the Origins of Life

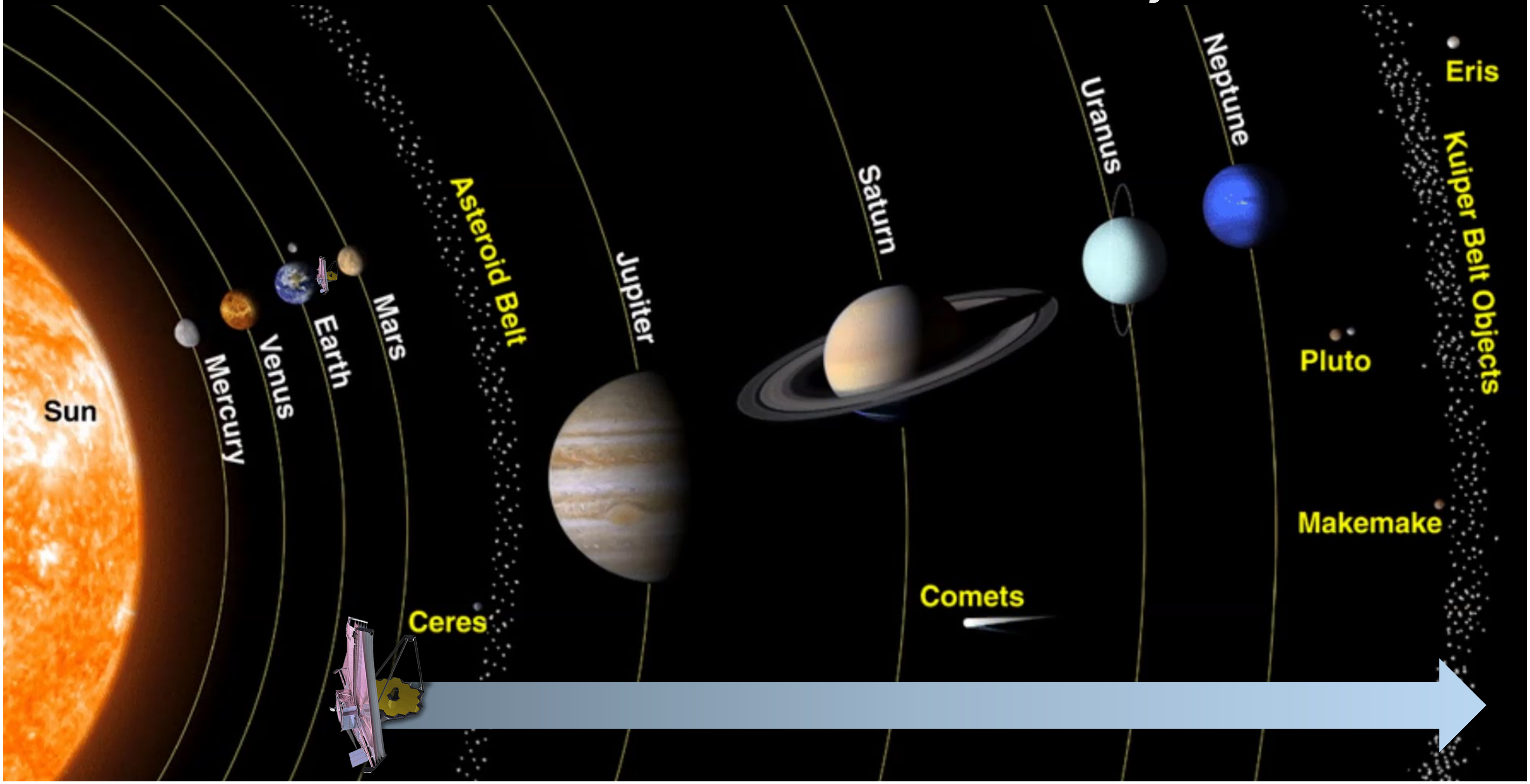


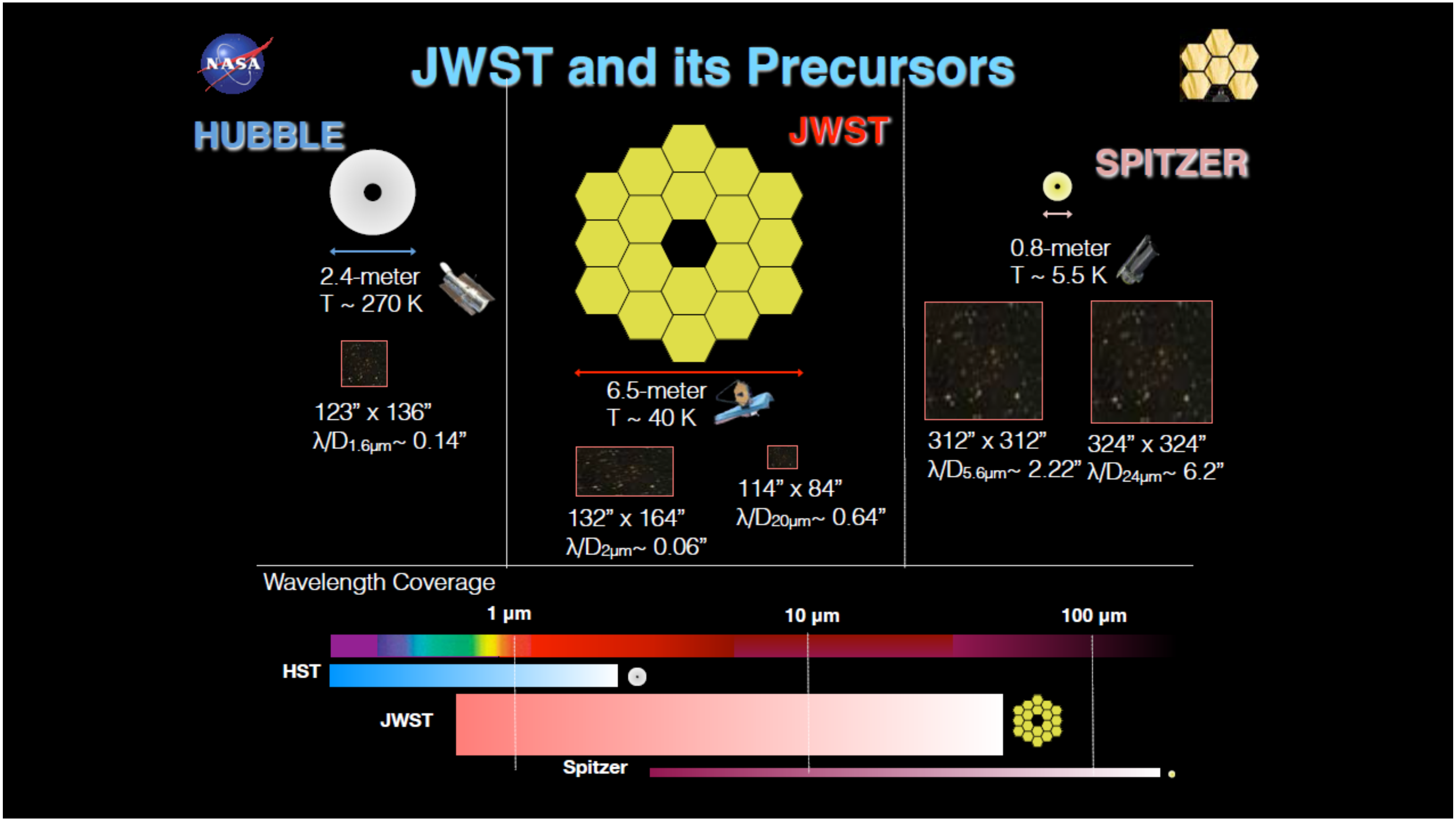

JWST: Planetary Systems and the Origins of Life
determine the physical and chemical properties of planetary systems (including our own) and assess where the building blocks of life may be present
Image Credit: Robert Hurt

JWST observations within our Solar System



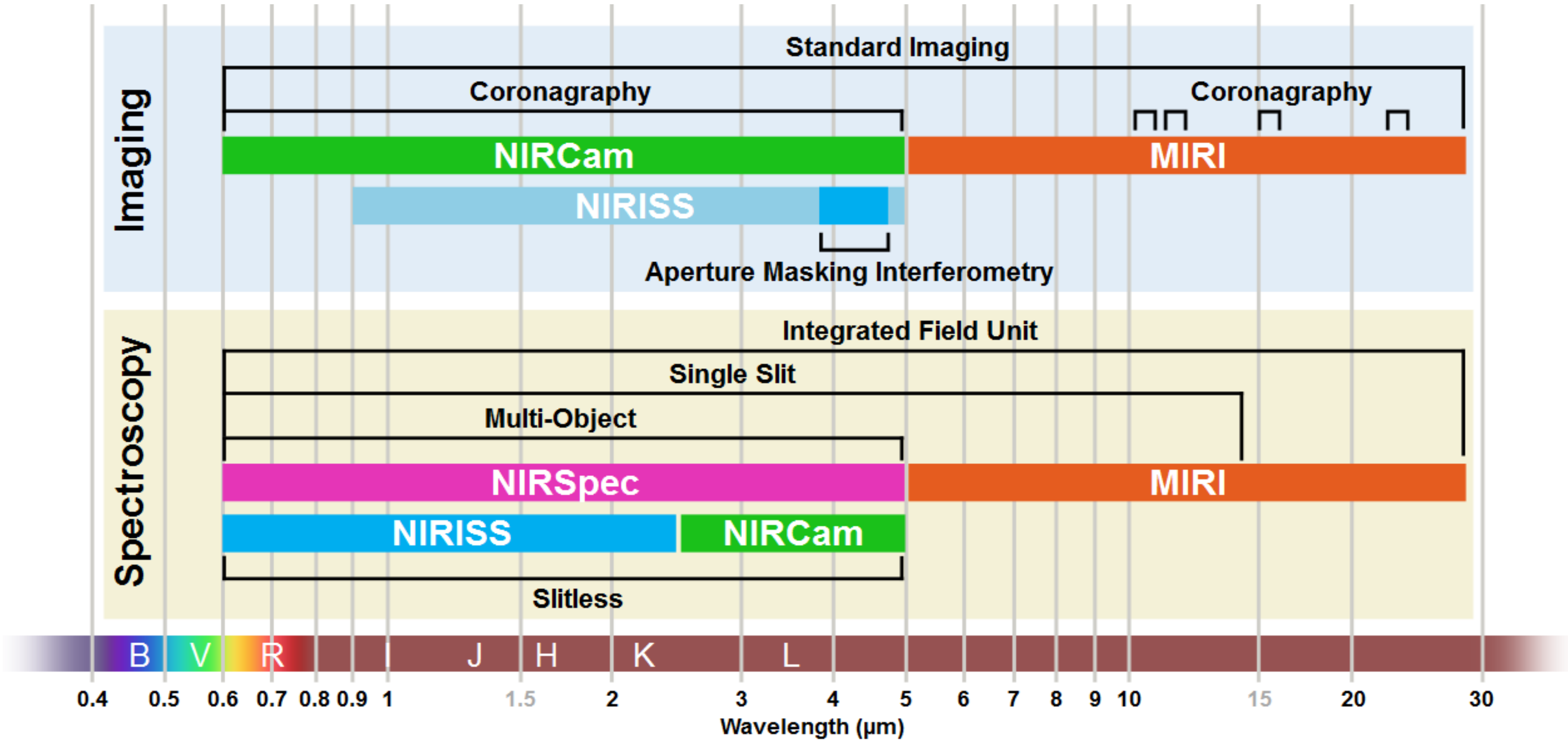
JWST observations within our Solar System





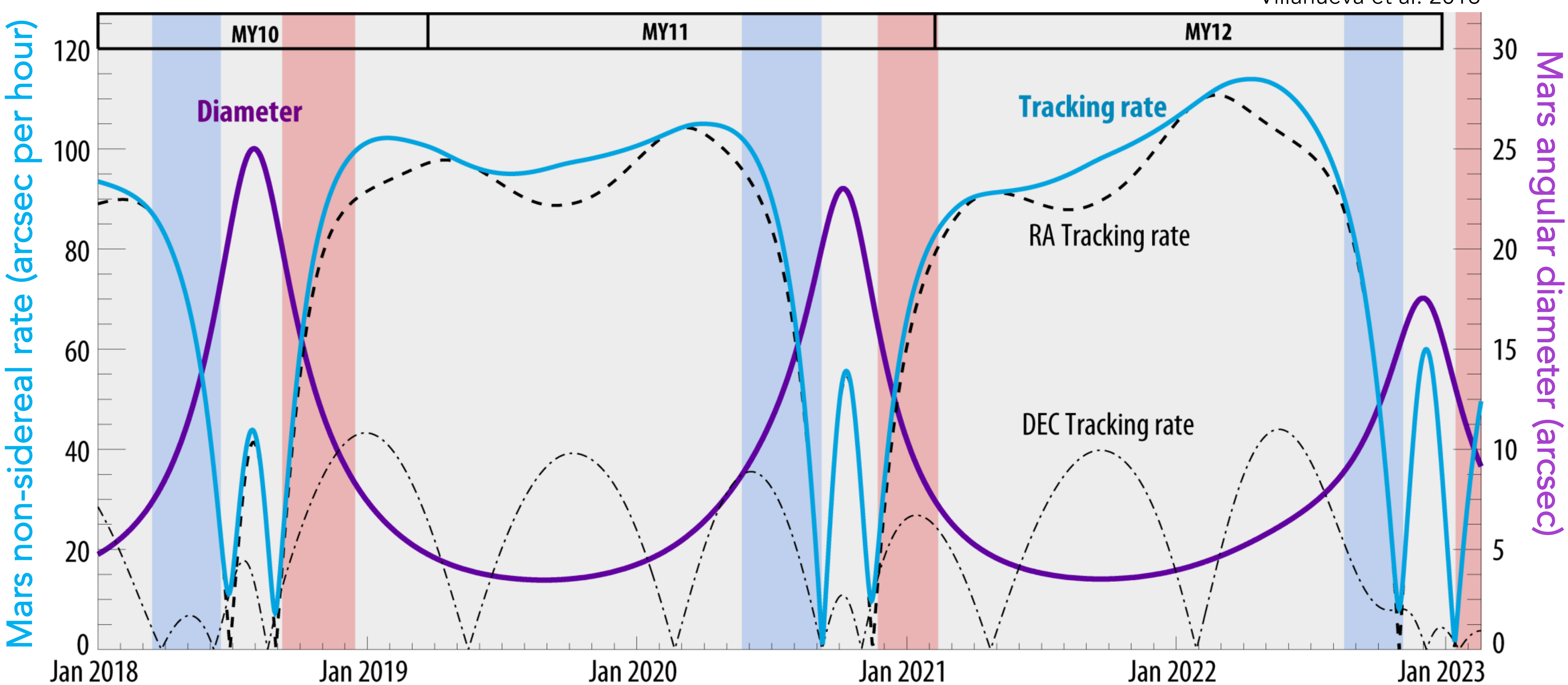
JWST and its Precursors
HUBBLE
2.4-meter
T ~ 270 K
123" x 136"
λ/D1.6μm~ 0.14"
JWST
6.5-meter
T ~ 40 K
132" x 164"
λ/D2μm~ 0.06"
114" x 84"
λ/D20μm~ 0.64"
SPITZER
0.8-meter
T ~ 5.5 K
312" x 312"
λ/D5.6μm~ 2.22"
324" x 324"
λ/D24μm~ 6.2"
Wavelength Coverage
1 μm
10 μm
100 μm
HST
JWST
Spitzer

JWST Instrumentation

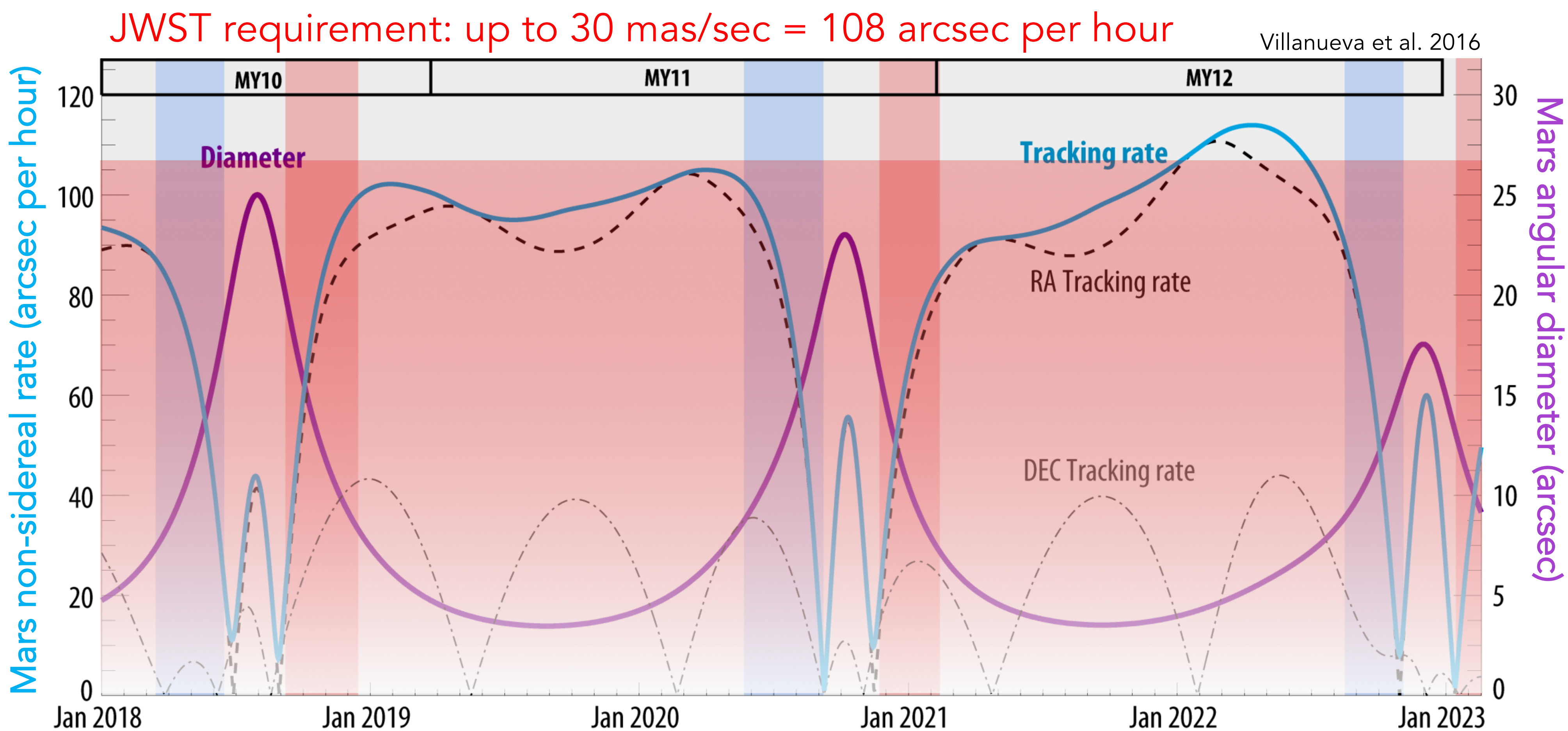


Mars motion & size

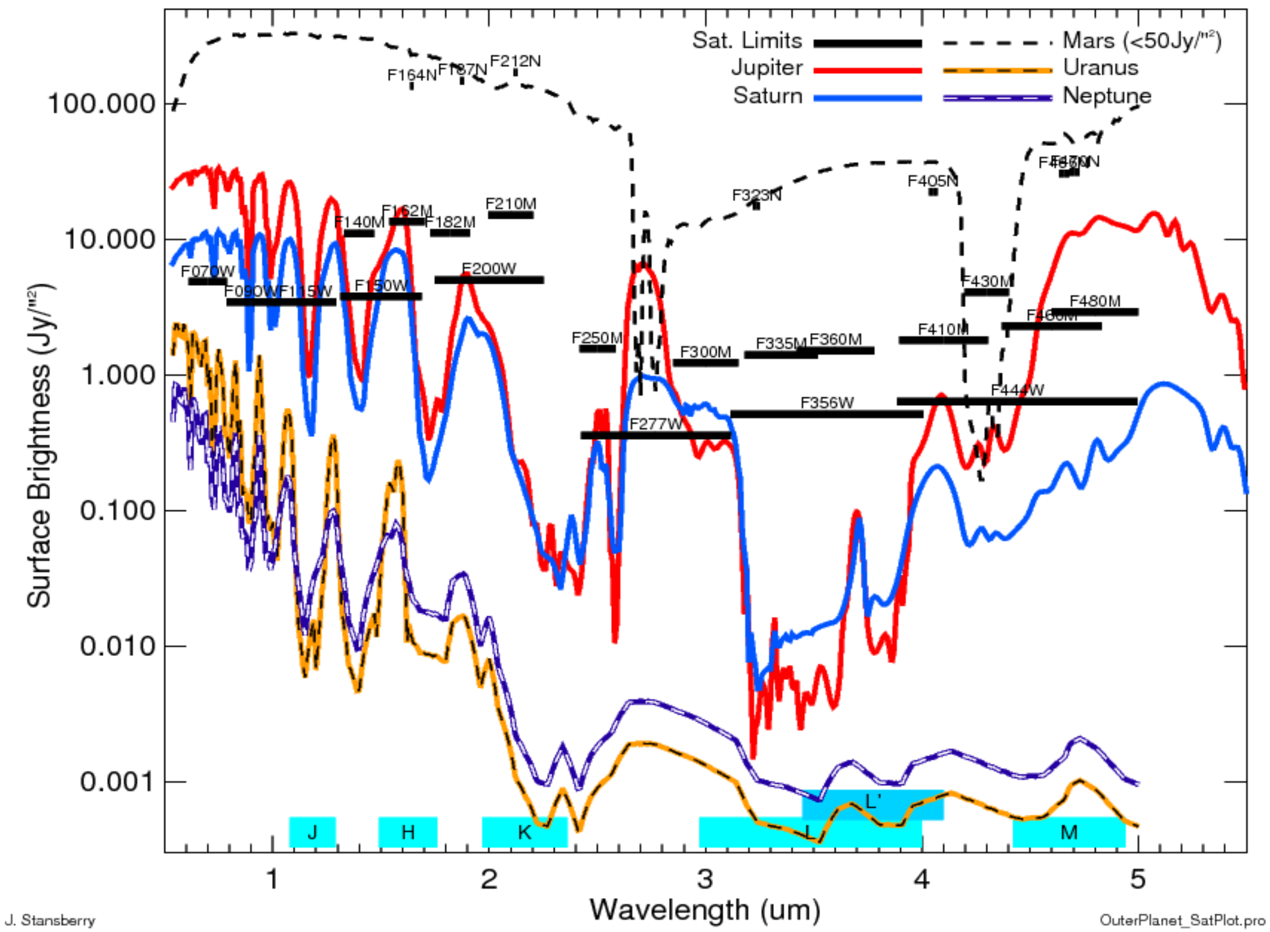
Villanueva et al. 2016



Mars motion & size versus JWST non-sidereal track rate

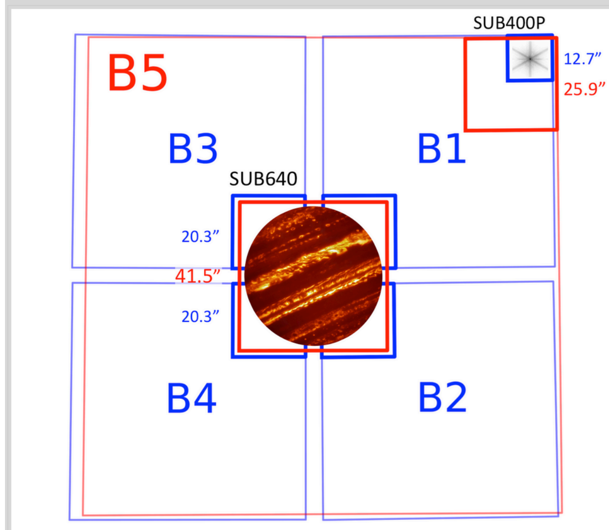


JWST saturation limits for bright planets (Mars, J, S, U, N)



NIRCam subarray
640 pixels = 40″

Figure 2. Visualizations of imaging subarrays



Demonstrations of the ***SUB640*** and ***SUB400P*** subarrays for imaging extended sources and point sources, respectively. When using ***SUB640*** in imaging mode, subarrays are read out from all five module B detectors. When using ***SUB400P*** in either imaging or time-series imaging mode, a subarray is read out from one detector in each wavelength channel. Center: Jupiter 5μm image obtained by VLT/VISIR (Credit: ESO/L. Fletcher) shown to scale with an angular diameter of 39". This diameter assumes (as in Norwood et al. 2016) that Jupiter is at a solar elongation of 90° and therefore in JWST's field of regard for observability. In the top right, the NIRCam point spread function in F200W, simulated by WebbPSF, is also shown to scale. Note the sizes in this figure may be outdated; refer to Table 1 for the most recent values.

https://jwst-docs.stsci.edu/near-infrared-camera/nircam-instrumentation/nircam-detector-overview/nircam-detector-subarray

Common types of JWST Observing Proposals

GO = General Observer (proposed new obs)

AR = Archival Proposals (data from archive)

GTO = Guaranteed Time Observations

- Investigators selected in 2003
- Instrument teams (4 teams)
- Interdisciplinary Scientists (6 selected)
- Others (Project Scientist, Telescope Scientist, etc)

JWST at NGAS Spacepark, approved public release #20-0288

DD-ERS = Director's Discretionary Early Release Science

- Investigators selected in 2017 (13 selected)
- No exclusive access period and can be used as a basis for Cycle 1 Archival Research (AR) Proposals

JWST Proposals for Solar System Science

GO and AR = PEOPLE MUST PROPOSE!

"You have to buy a lottery ticket to win the lottery!"

GTO = Guaranteed Time Observations

- Investigators selected in 2003
- Instrument teams (4 teams; some had interest in KBOs)
- Interdisciplinary Scientists (6 selected; 2 Solar System)
  - Jonathan Lunine, to study Titan, KBOs, and exoplanets: ~100 hours
  - Heidi Hammel, to study the Solar System: ~100 hours

DD-ERS = Director's Discretionary Early Release Science

- Investigators selected in 2017 (13 selected; 1 Solar System)
  - Imke de Pater and Thierry Forget, to study the Jupiter system

JWST GTO AR-accessible Solar System Programs

100% of de Pater/Forget ERS time
Jupiter System Science

Atmos Aurorae Io Ganymede Rings

Almost 100% of Hammel GTO time
Solar System Science

Asteroids and NEOs

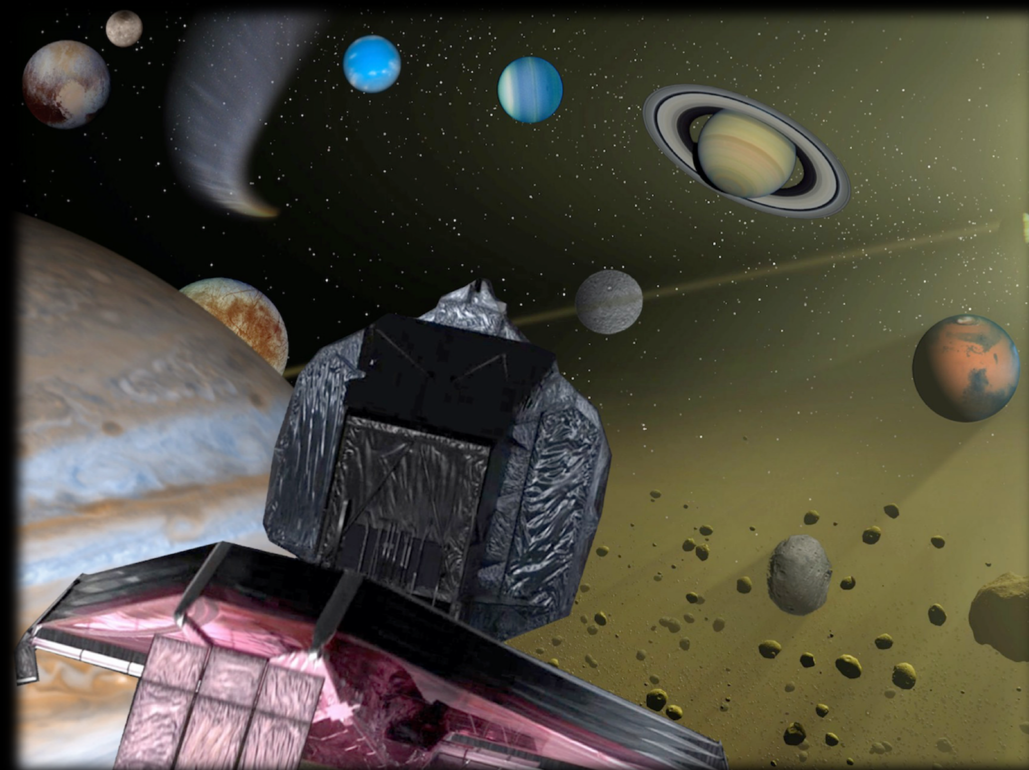
Comets   Mars

Jupiter, Saturn, Uranus, Neptune

Saturn's rings and small sats

Europa and Enceladus

Titan   KBOs   Occultations



Details on all GTO programs including Solar System:
https://jwst-docs.stsci.edu/display/JSP/JWST+GTO+Observation+Specifications

JWST GTO AR-accessible Solar System Programs

100% of de Pater/Forget ERS time
Jupiter System Science

Atmos Aurorae Io Ganymede Rings

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Solar System Science

Asteroids and NEOs

Comets Mars

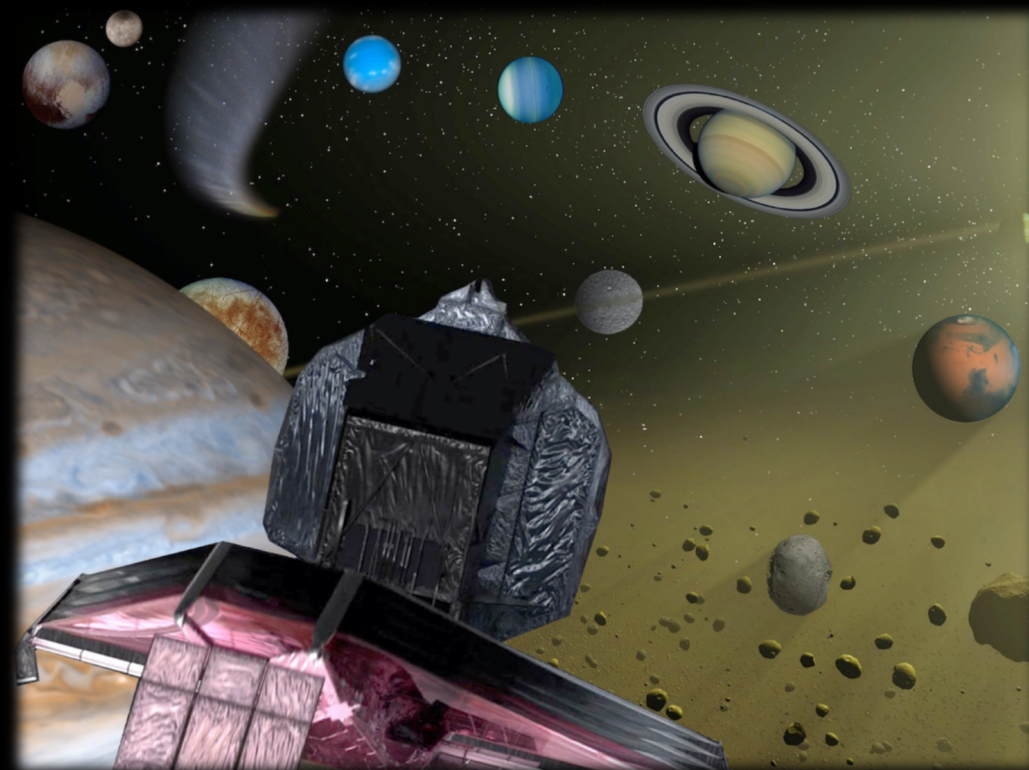
Jupiter, Saturn, Uranus, Neptune

Saturn's rings and small sats

Europa and Enceladus

Titan ~~KBOs~~ Occultations

KBOs are shared with instrument teams, who have not waived proprietary time



Details on all GTO programs including Solar System:
https://jwst-docs.stsci.edu/display/JSP/JWST+GTO+Observation+Specifications

JWST GTO Solar System Science Team

Cristina Thomas
NEOs

Andy Rivkin
Asteroids & Trojans

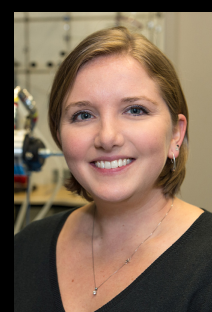
Pablo Santos-Sanz
Occultations

Geronimo Villanueva
Mars, Europa, & Enceladus

Matt Tiscareno
Saturn’s rings & small sats

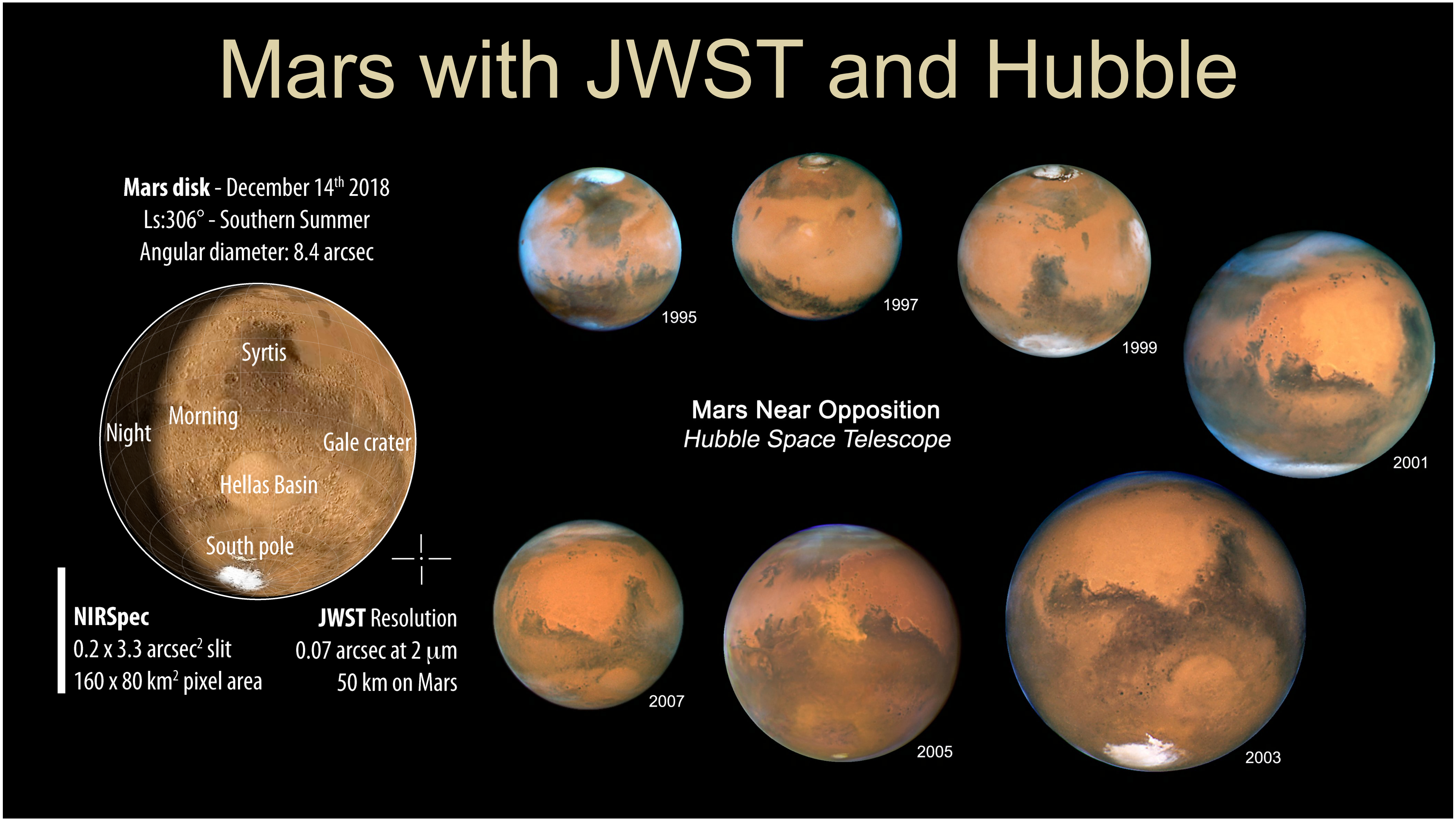
Leigh Fletcher
Atm: Jup, Sat, Ura, & Nep

Alex Parker & John Stansberry
KBOs

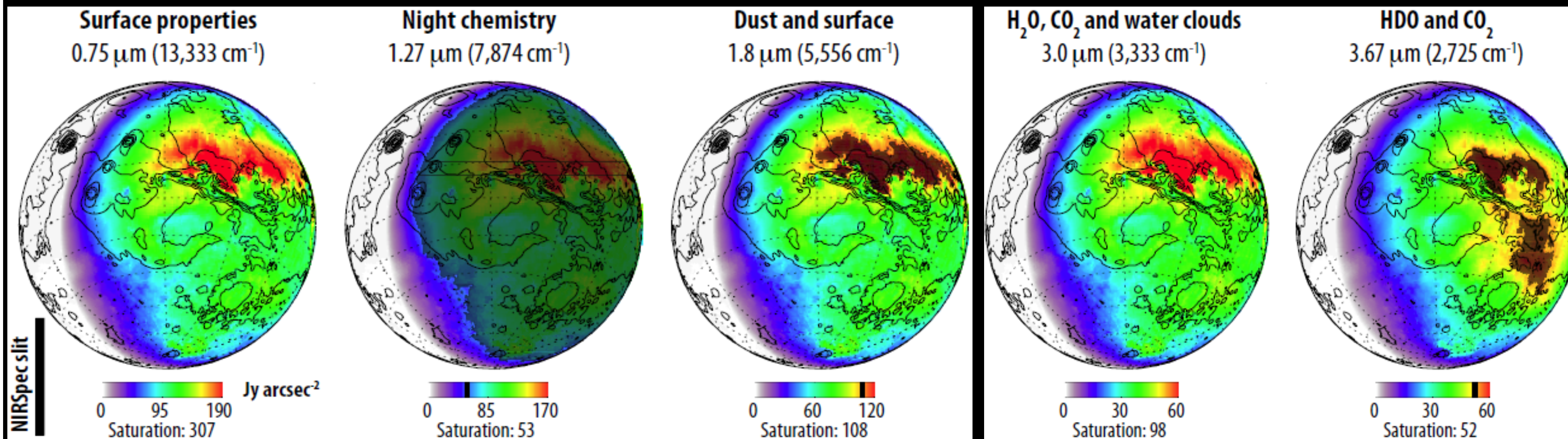


Michael Kelley & Stefanie Milam
Comets

Conor Nixon & Jonathan Lunine
Titan

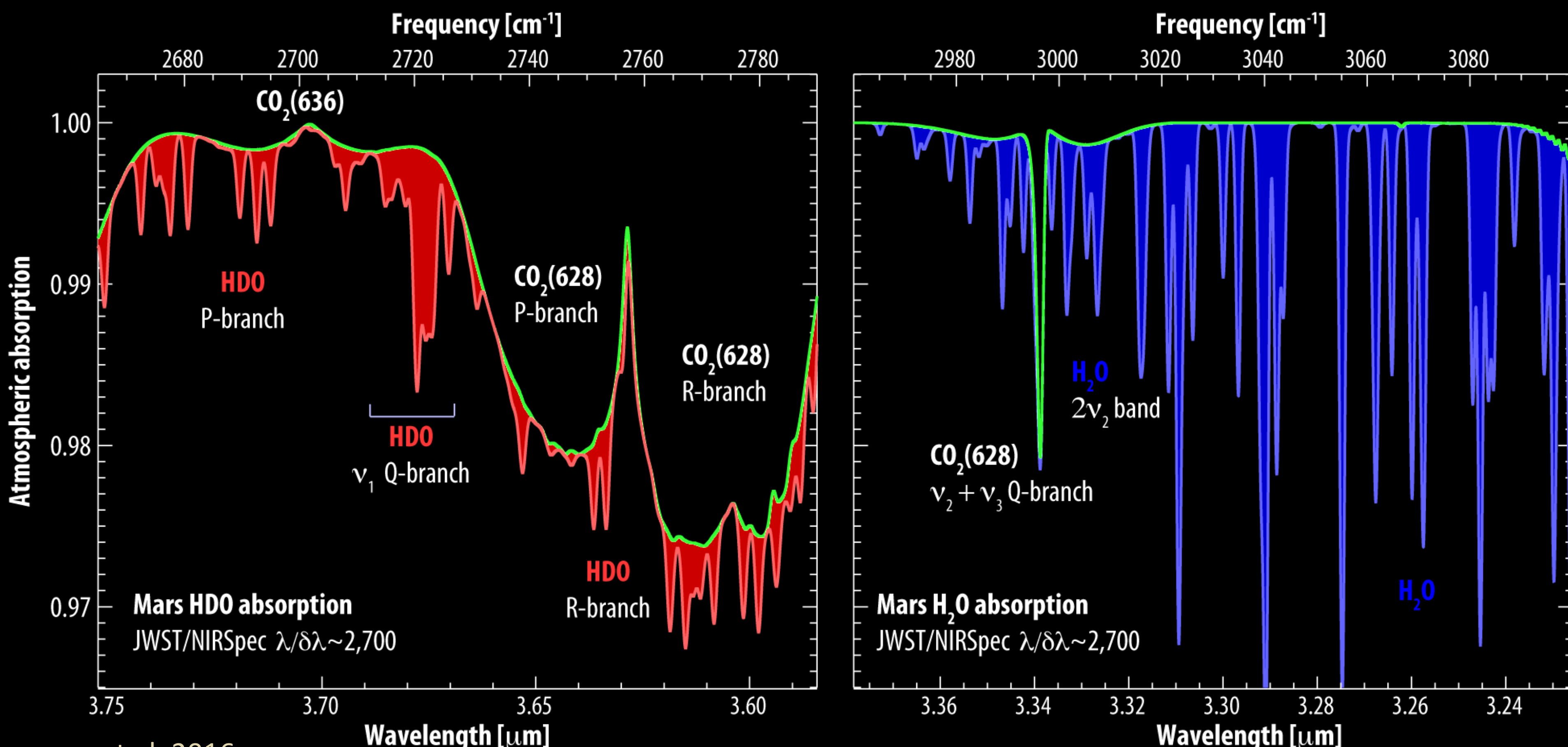

Mars with JWST and Hubble
Mars disk - December 14th 2018
Ls:306° - Southern Summer
Angular diameter: 8.4 arcsec
Syrtis
Morning
Night
Gale crater
Hellas Basin
South pole
NIRSpec
0.2 x 3.3 arcsec² slit
160 x 80 km² pixel area
JWST Resolution
0.07 arcsec at 2 μm
50 km on Mars
Mars Near Opposition
Hubble Space Telescope
1995
1997
1999
2001
2007
2005
2003

JWST global maps of Mars: surface, dust, organics



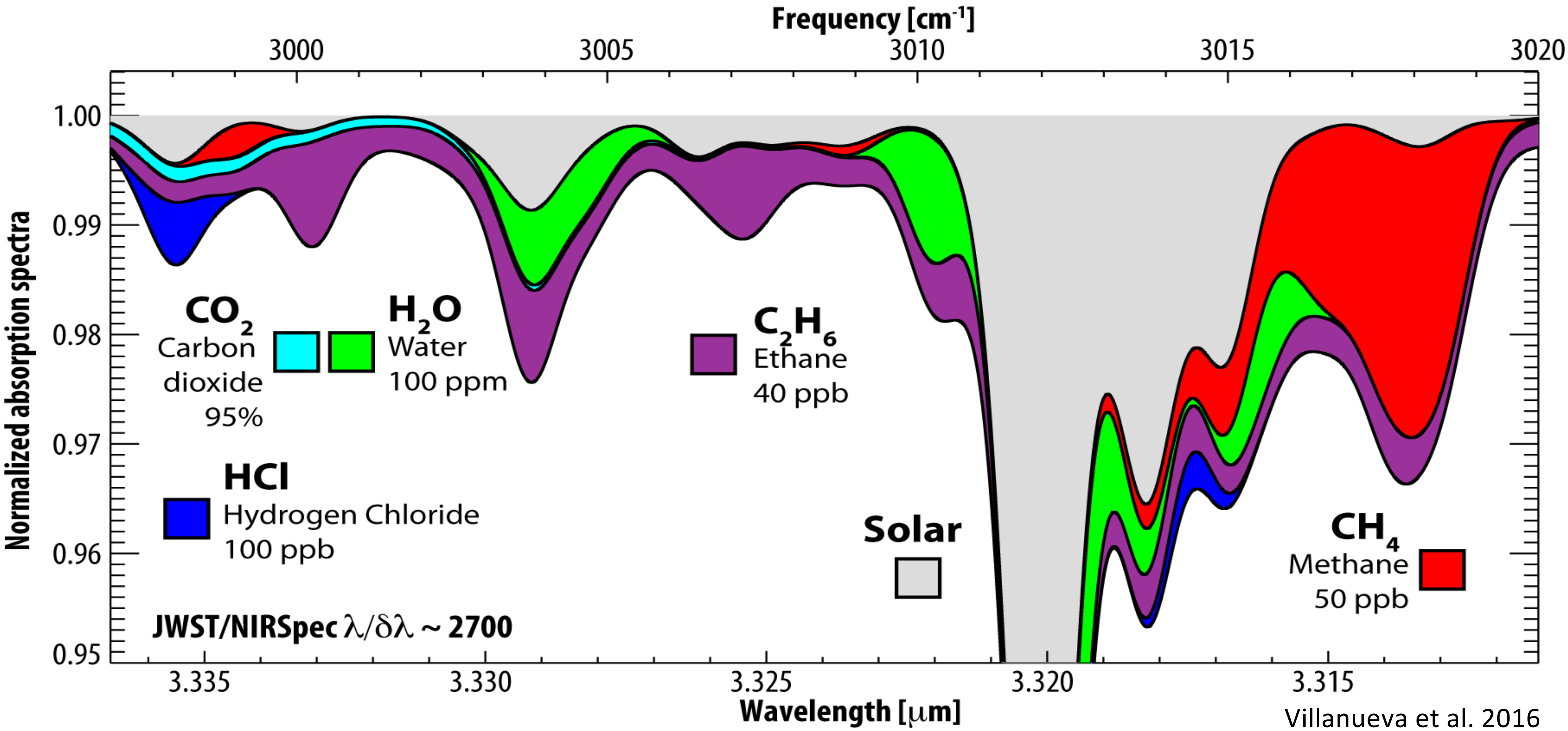
Simulations by Geronimo Villanueva

HDO and H_2O with NIRSpec



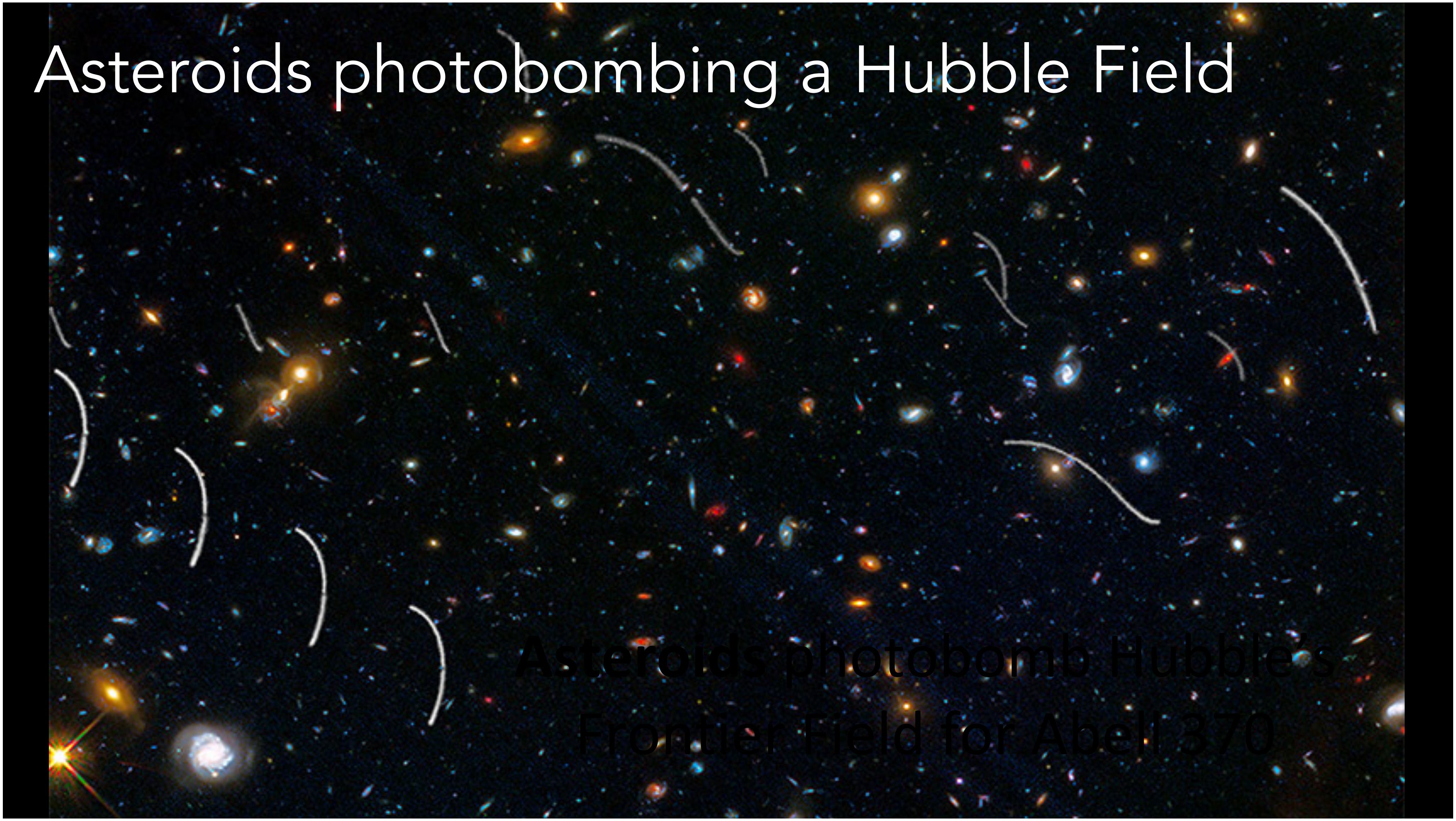
Villanueva et al. 2016

Organics on Mars



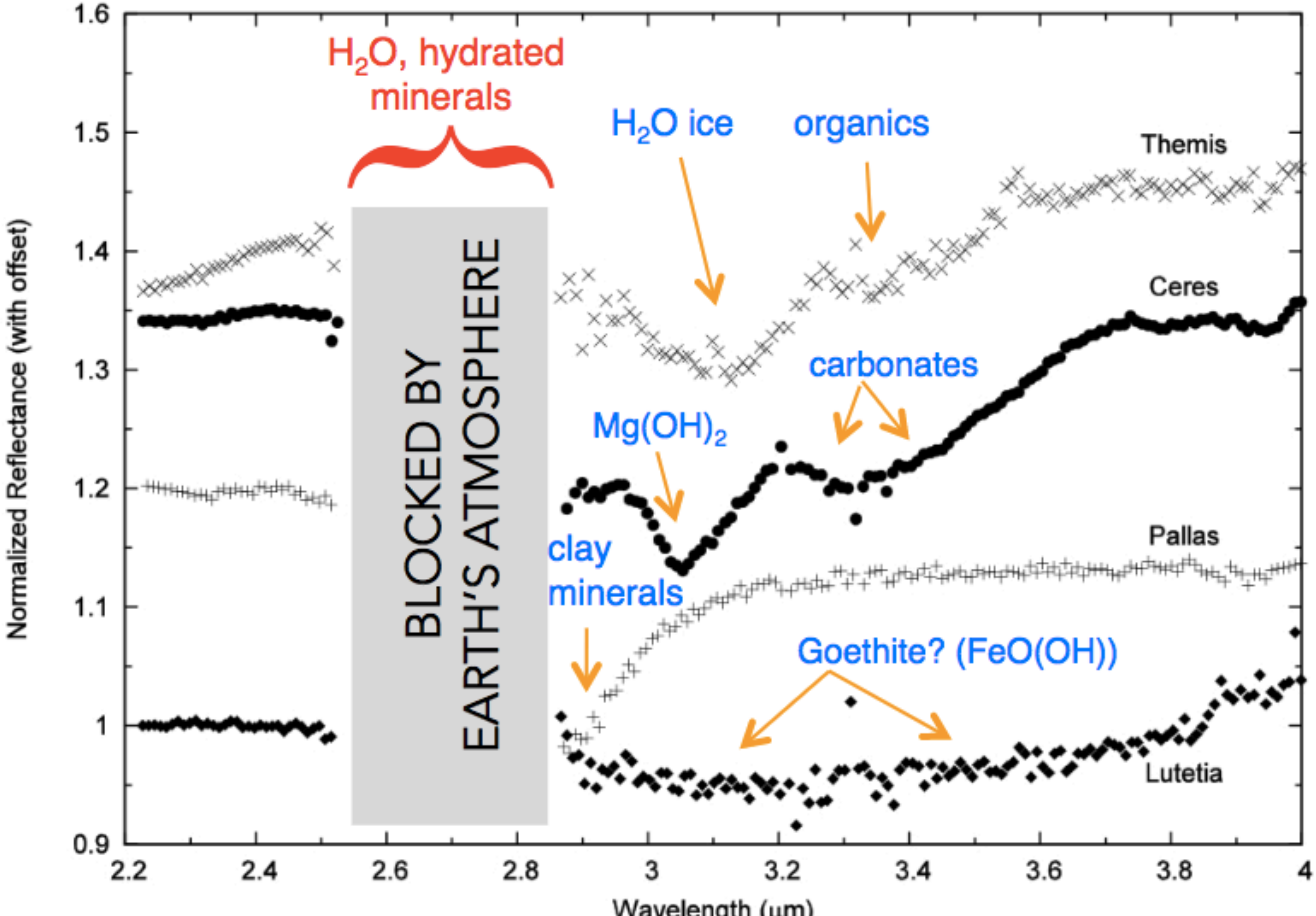
Villanueva et al. 2016

Asteroids photobombing a Hubble Field



Asteroids photobomb Hubble's Frontier Field for Abell 370

Motivation
Asteroids have natures ranging from the solar system's earliest solids to the last stages before full planethood. JWST observations will provide a critical link between meteorite samples and rare spacecraft missions.
Composition
Expanded wavelength coverage will further our understanding of asteroid compositions for all populations.
Surface Features
Dozens of main-belt asteroids large enough to be compositionally mapped by NIRCam
Size/Brightness Limits
NIRSpec can obtain S/N > 10 in 1000 s or less for practically every known main belt asteroid.
Asteroids and the James Webb Space Telescope:
Rivkin, Marchis, Stansberry, Takir, Thomas et al.
http://arxiv.org/abs/1510.08414
Are the compositions of primaries and secondaries similar?
How does Space Weathering affect the surface of asteroids?
Solar Wind
How do asteroids link to known meteorite classes?
How does hydration vary across the Main Belt?
Which volatile species are present on asteroid surfaces?
What amount of volatiles are present?
Are spectrally red surfaces due to organics?
What are the physical properties of an asteroid's surface?
Andy Rivkin & Cristina Thomas

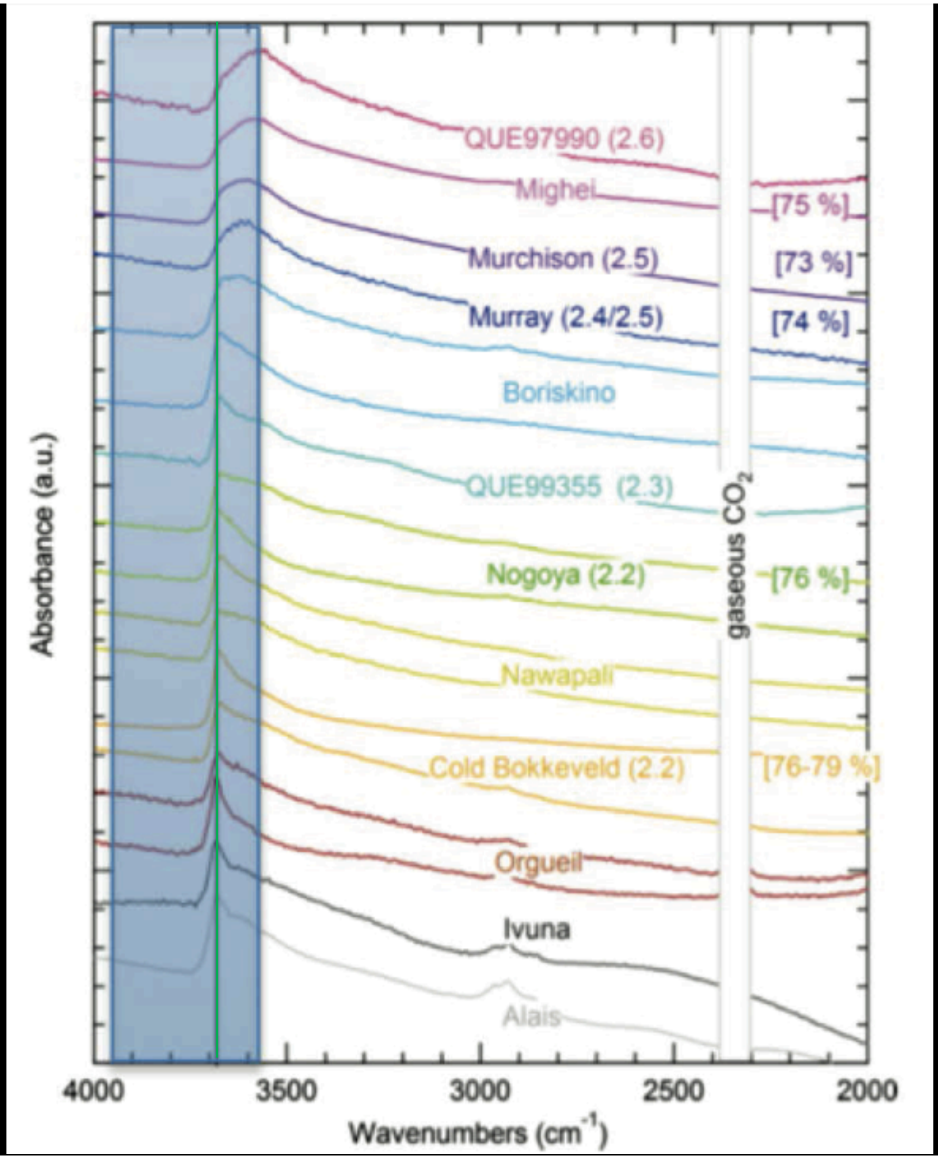


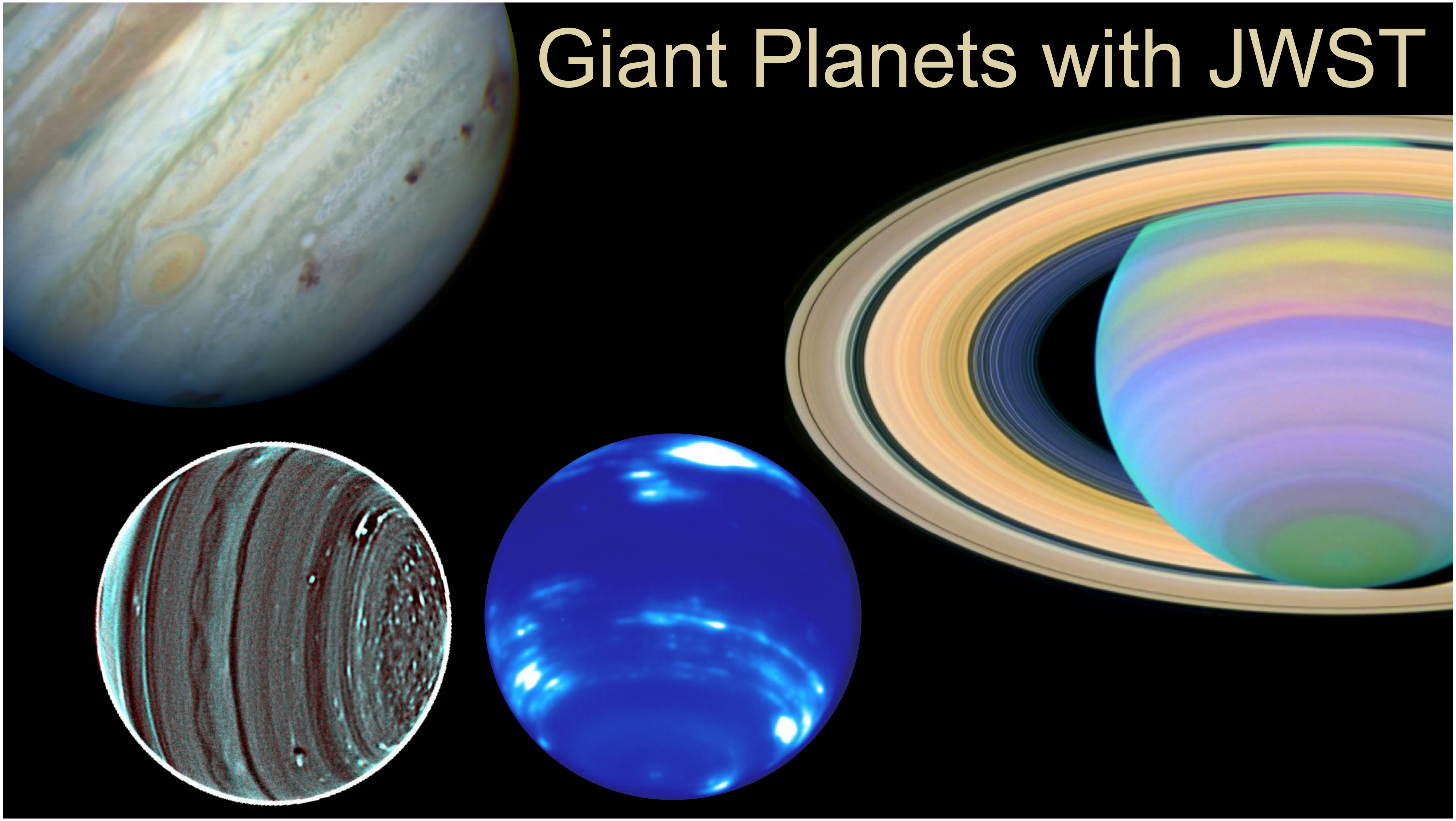
From presentation by Sonneborn et al.

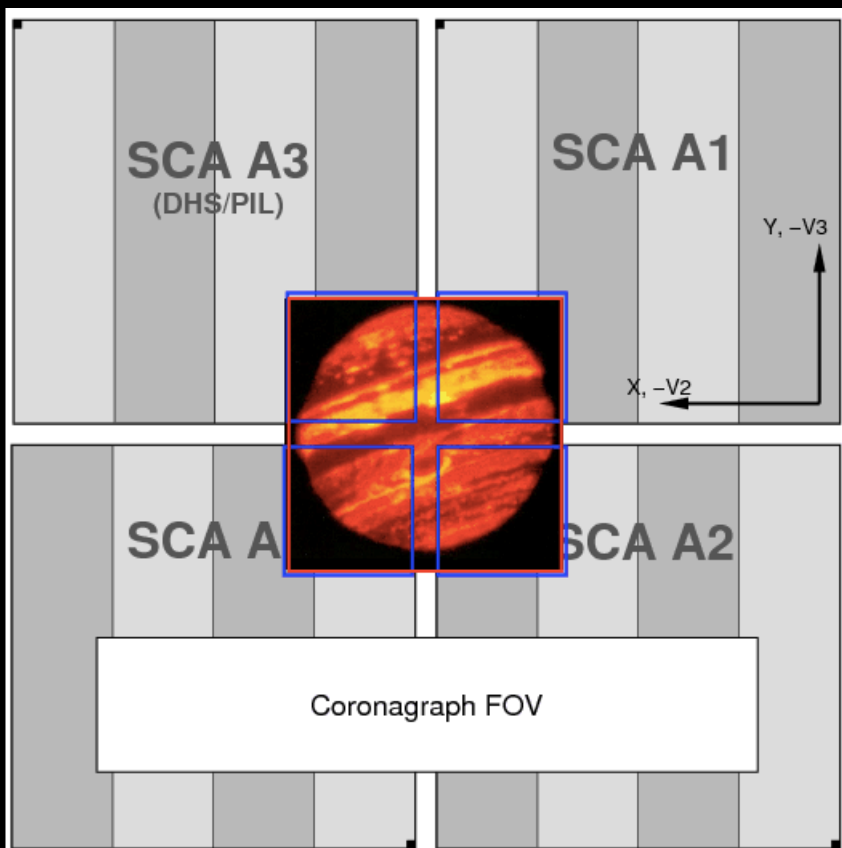
From Rivkin et al.
JWST white paper for asteroids

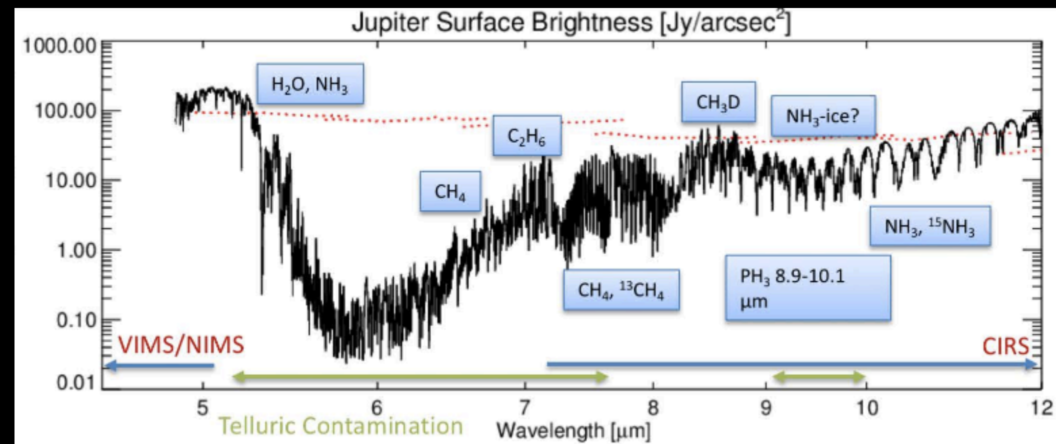
adapted from Beck et al. (2010): the band near 3700 cm^{-1} (due to hydroxyl in silicates) systematically changes as a function of metamorphic grade

the variation is in a wavelength region entirely blocked by the Earth's atmosphere (blue shaded region), making JWST a unique facility to study this variation




Giant Planets with JWST



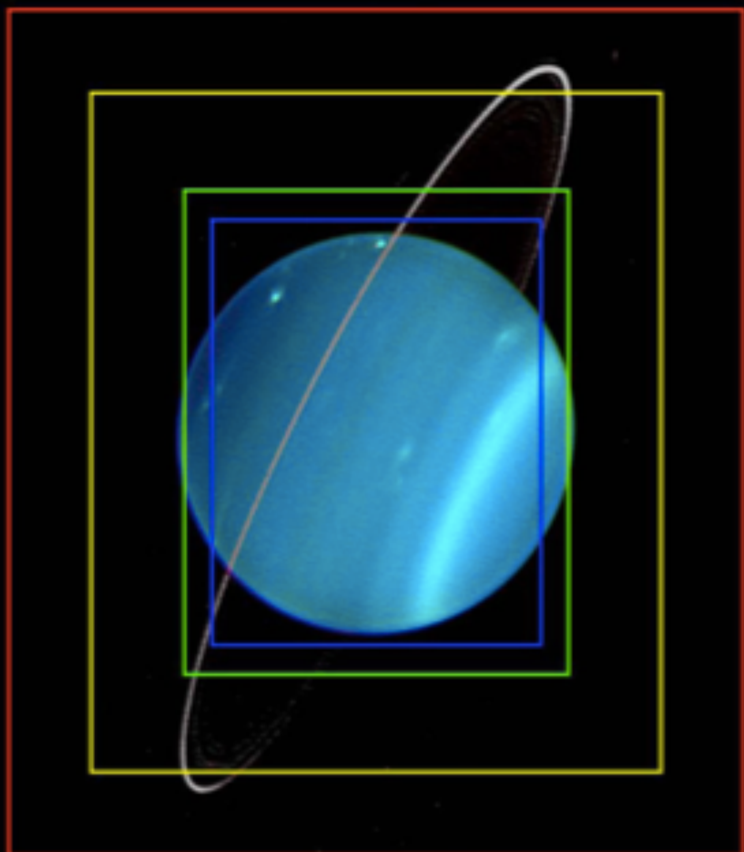


For **Jupiter**, 5-micron window provides:

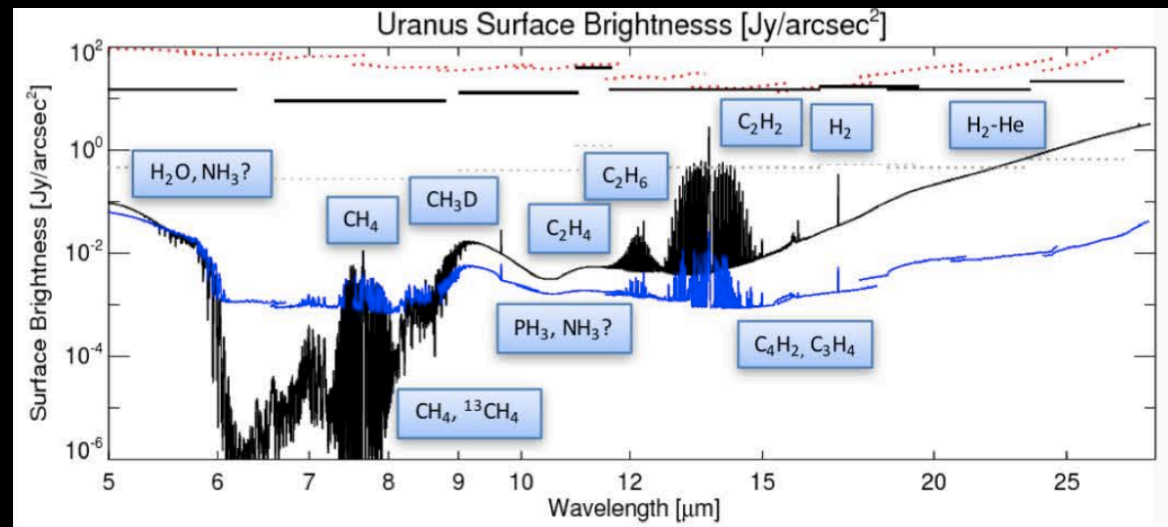
- *Possible signatures of chromophores*
- *Stratospheric structure*
- *Access to fresh ice material*
- *Ammonia, ethane, phosphine*

Subarrays provide ability to observe bright targets like **Jupiter** and **Saturn**

Giant Planet Atmospheres Team led by Leigh Fletcher



MIRI IFU field of view compared with **Uranus**

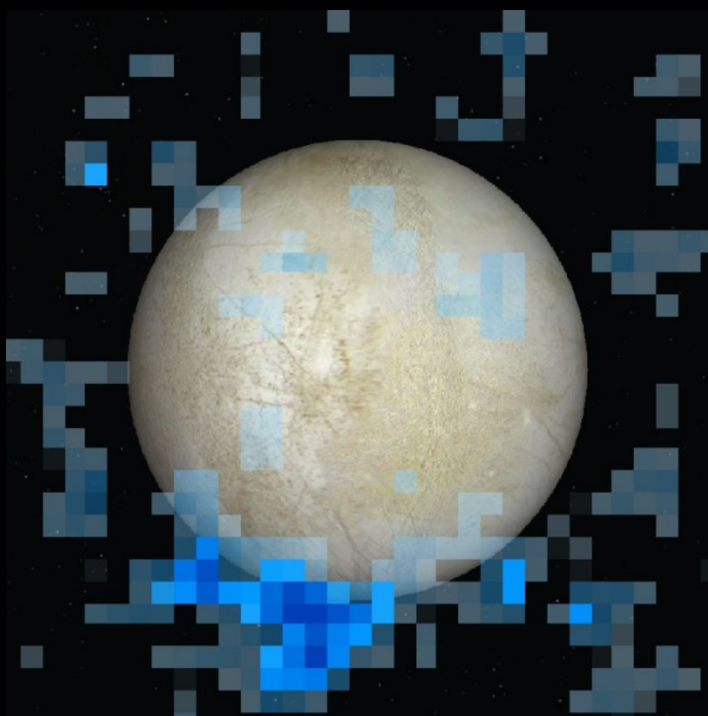


For **Uranus** and **Neptune:** temperature and winds as a function of altitude, to relate circulation to the banded weather patterns, as well as ortho/para H_2 ratios; stratospheric hydrocarbon abundances; volatiles distributions (e.g., NH_3, H_2S); disequilibrium species (PH_3); clouds and aerosols

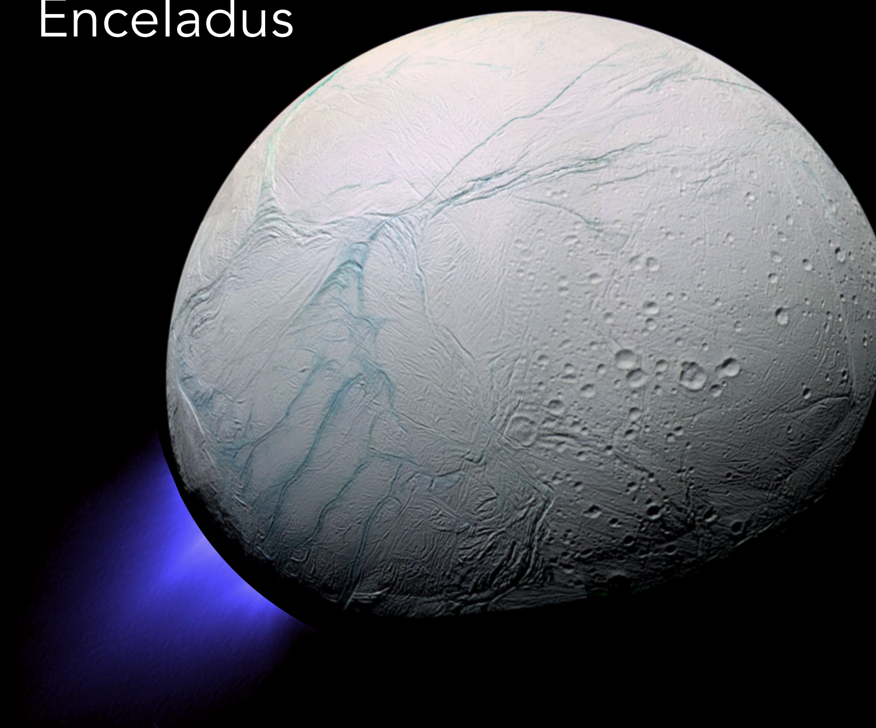
Giant Planet Atmospheres Team led by Leigh Fletcher

Exploring ocean worlds

Jupiter's moon
Europa



Saturn's moon
Enceladus



Probing the sub-surface oceans of Europa and Enceladus with JWST

Geronimo Villanueva, GSFC

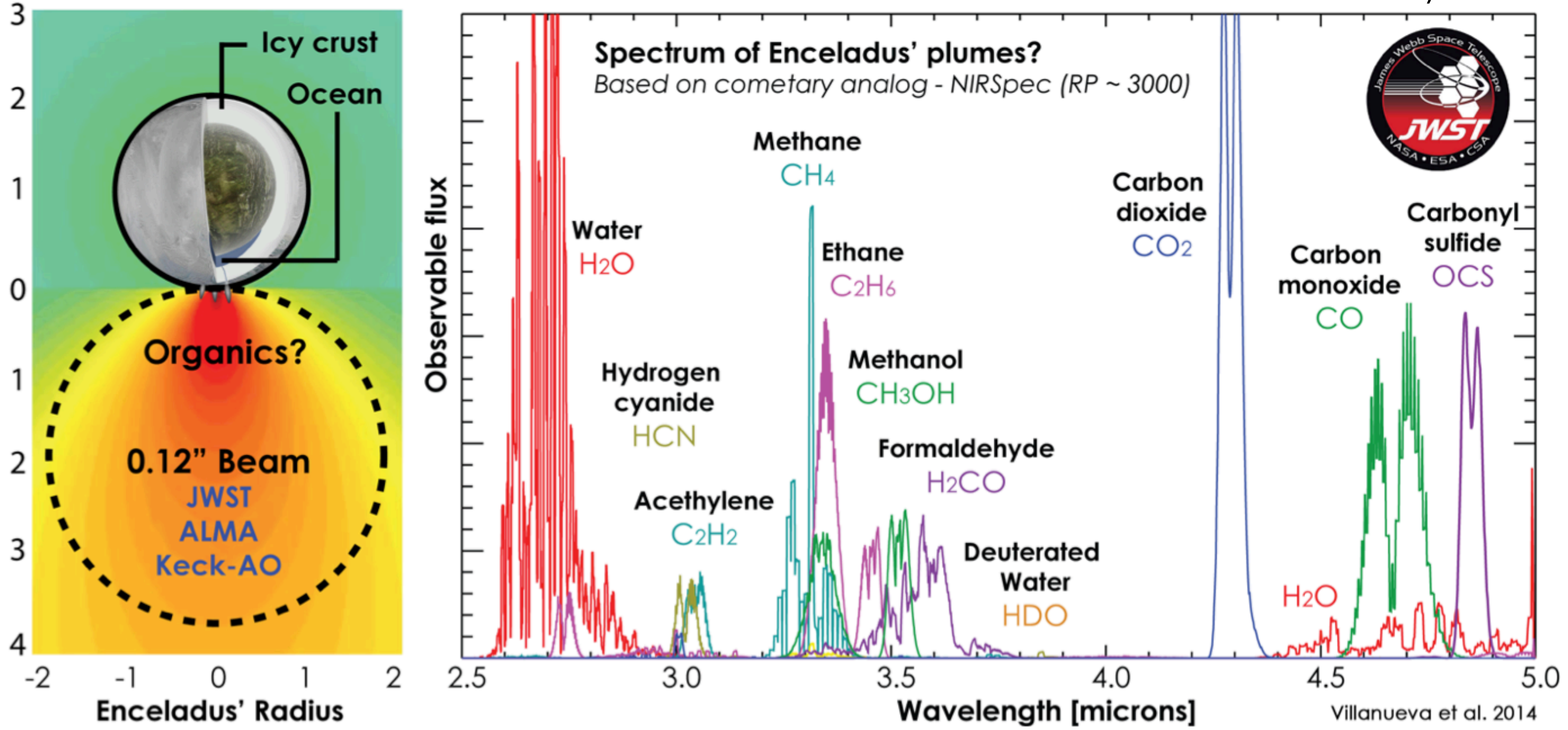
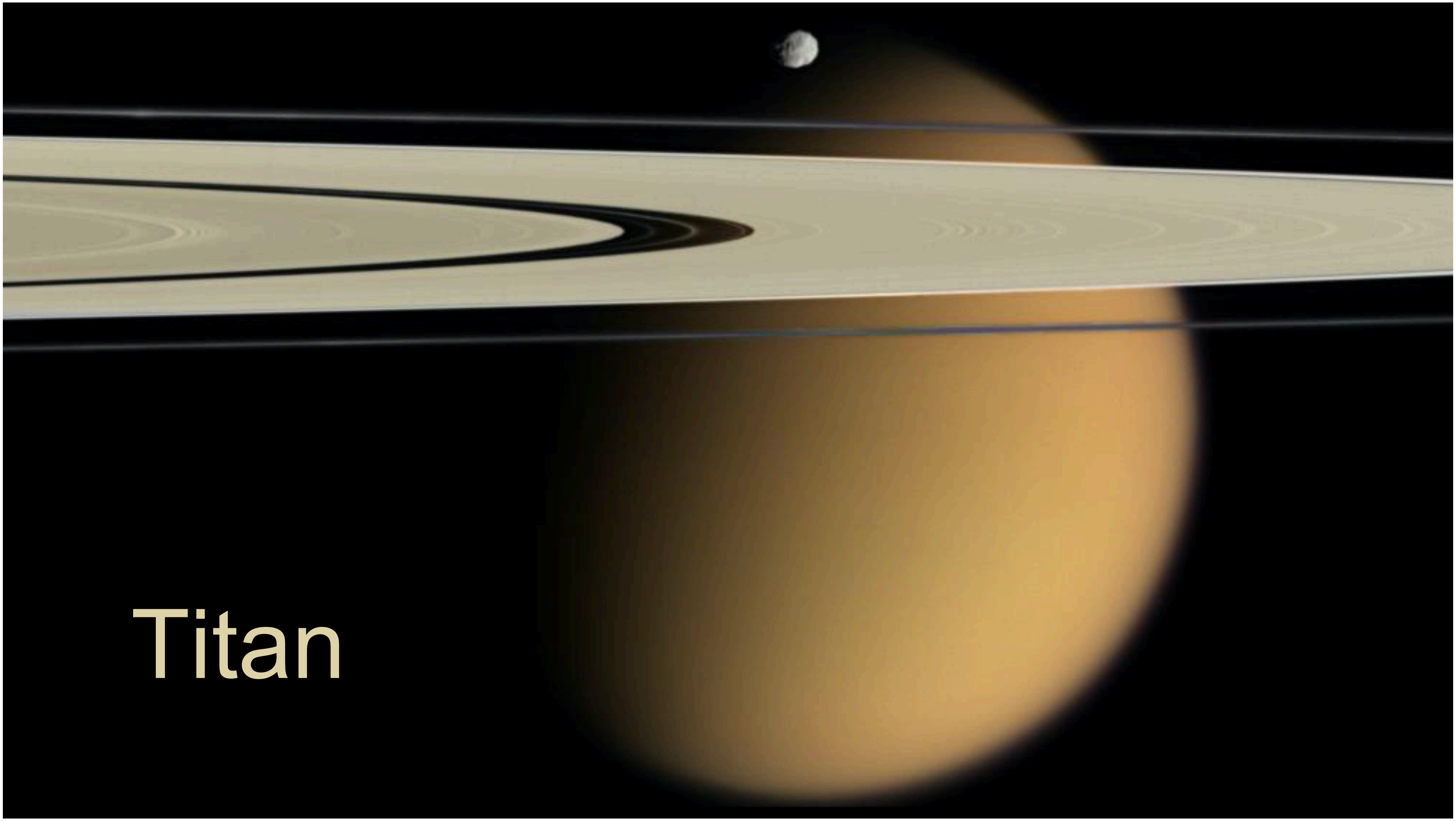
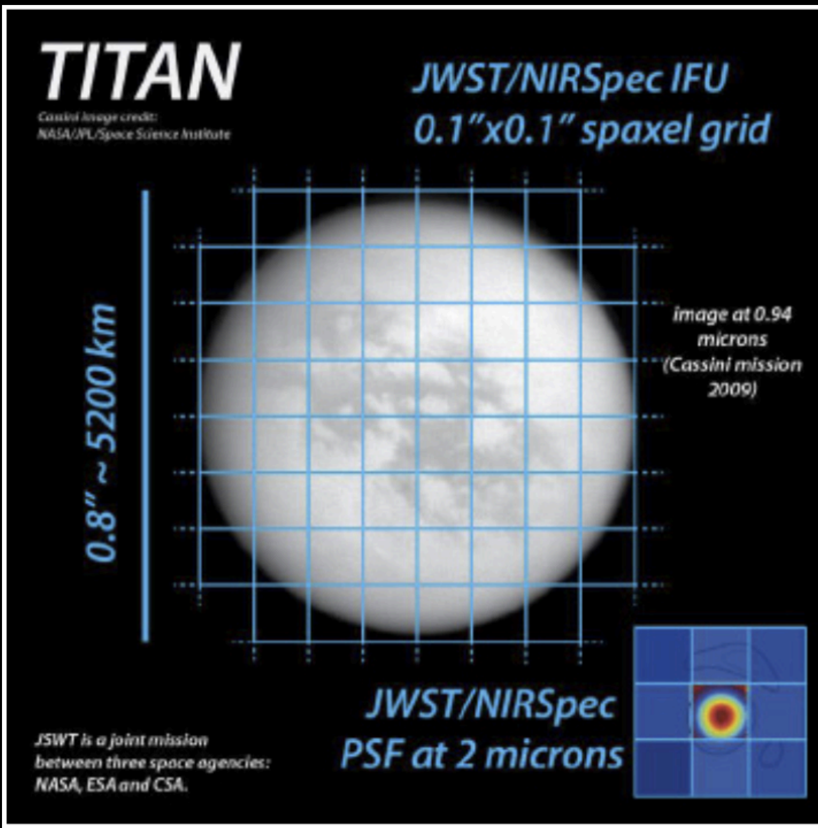
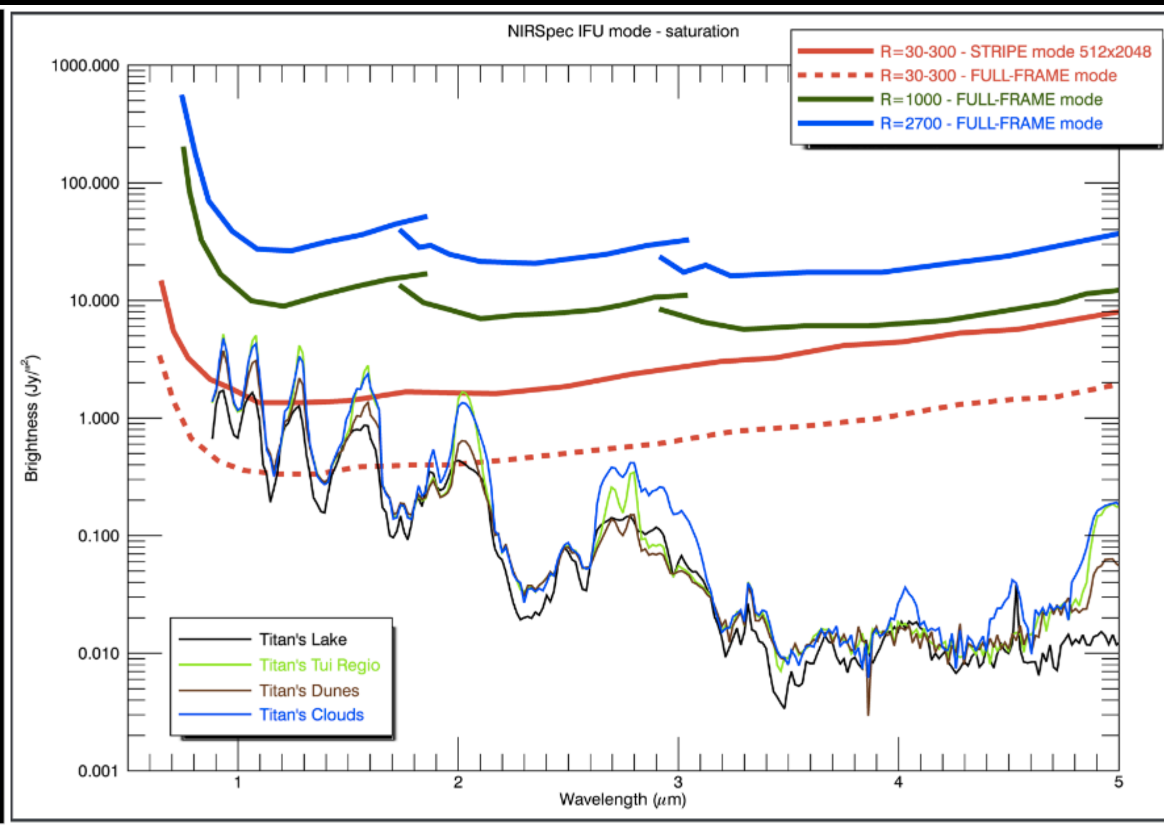


Figure 1: JWST will be able to address fundamental questions about Europa and Enceladus: How habitable are these sub-surface environments? Are these bodies rich in organic material? What drives the plumes? Do tidal interactions with the gas-giants affect the stability and evolution of these plumes and the sub-surface oceans?


Titan

Spatially and Spectrally resolved Titan studies

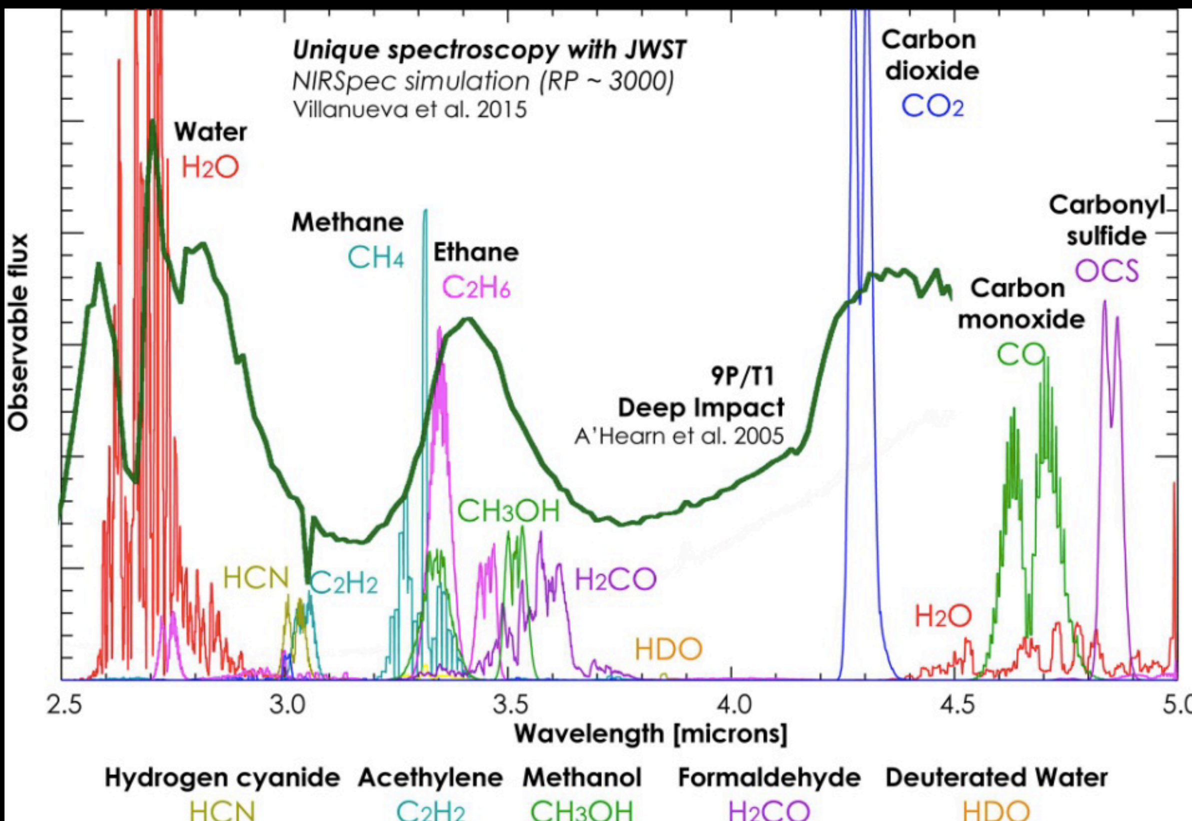




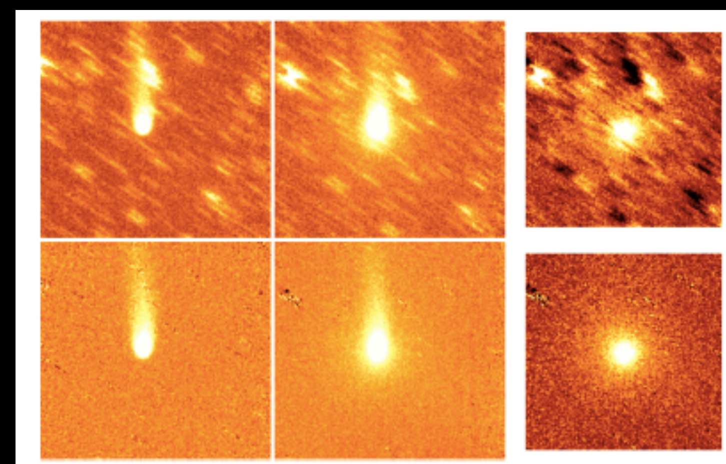
Comet 21P/Giacobini-Zinner on August 14, 2018 (image credit and copyright: Rolando Ligustri)

Comet spectroscopy and imaging

Observations led by Michael Kelley and Stefanie Milam

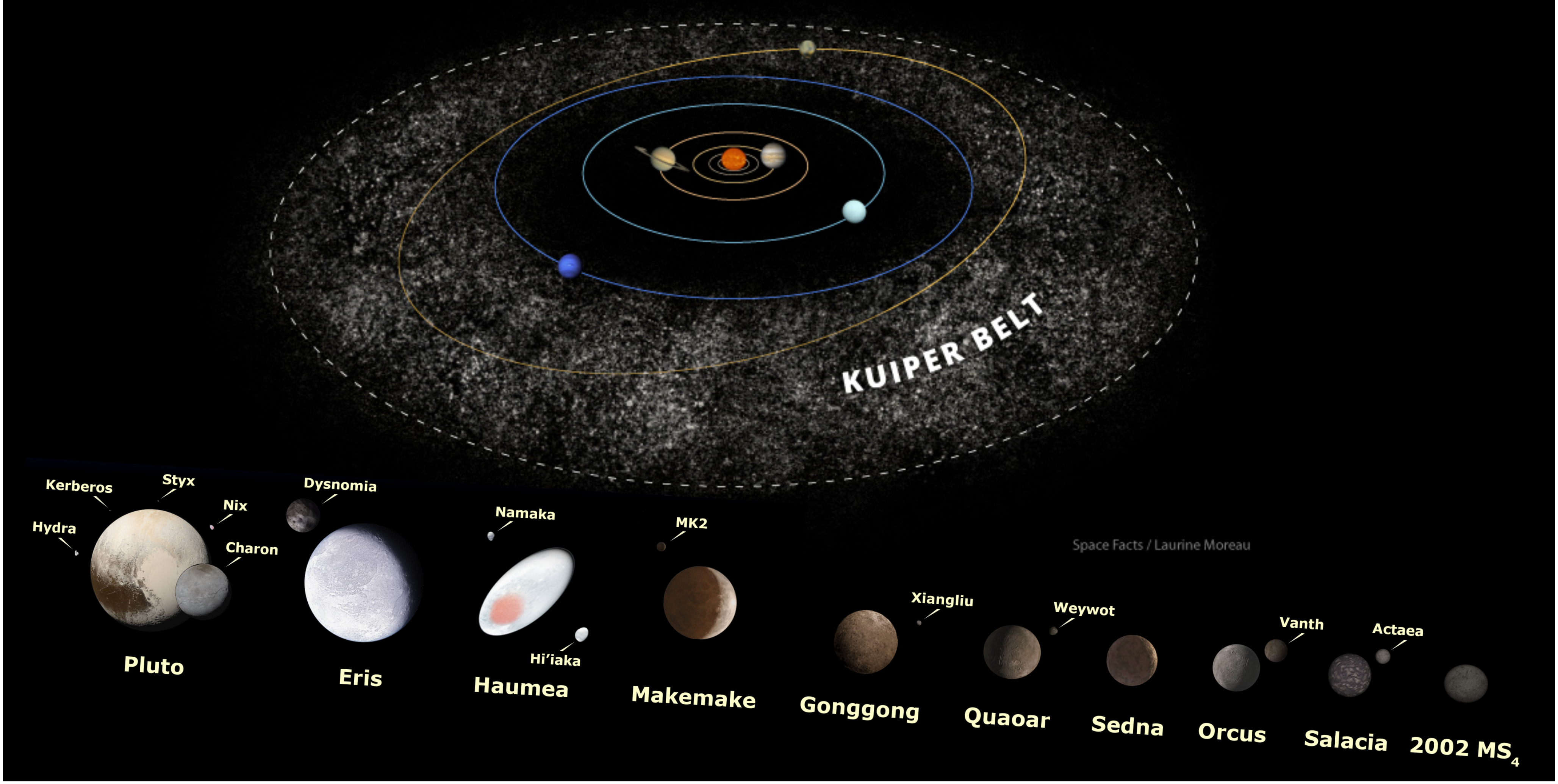


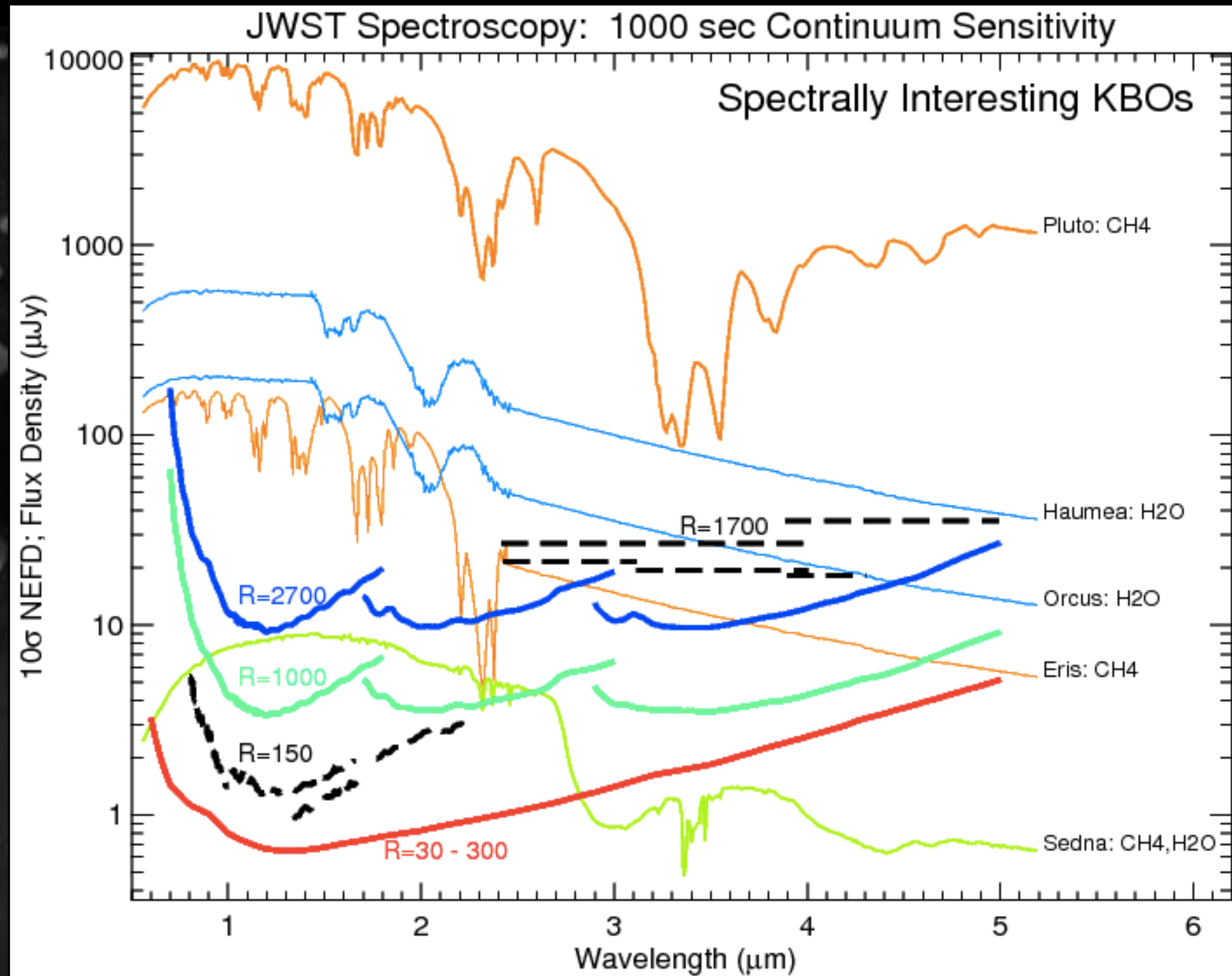
Many key molecular features are found at JWST's wavelengths



IR filters distinguish gas vs dust in comae (M. Kelley Spitzer data)

JWST can *characterize nearly every Kuiper Belt Object known to date*

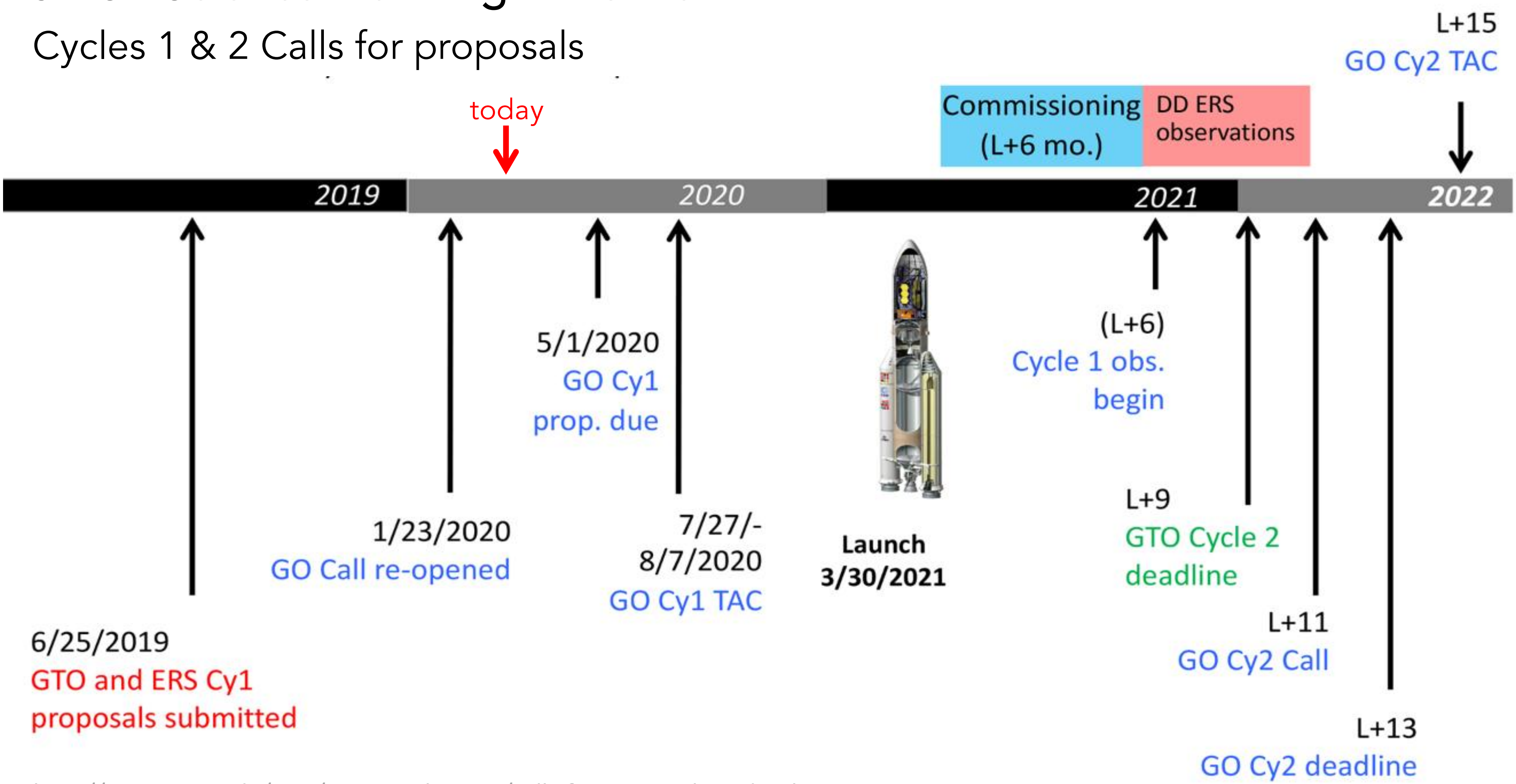



JWST Spectroscopy: 1000 sec Continuum Sensitivity
Spectrally Interesting KBOs
10σ NEFD; Flux Density (μJy)
Wavelength (μm)
10000
1000
100
10
1
1
2
3
4
5
6
Pluto: CH4
Haumea: H2O
Orcus: H2O
Eris: CH4
Sedna: CH4,H2O
R=1700
R=2700
R=1000
R=150
R=30 - 300

Cycle 1 Call for JWST Proposals

JWST Science Planning Timeline

Cycles 1 & 2 Calls for proposals



http://www.stsci.edu/jwst/science-planning/calls-for-proposals-and-policy

JWST Cycle 1 GO Proposal Call – due 1 May 2020

Program Category	Size	Estimated Allocation*
Small programs	≤25 hours	3,500 hours
Medium programs	>25 and ≤75 hours	1,500 hours
Large programs	>75 hours	1,000 hours

Cycle 1 GO call supports Calibration Proposals, Long-Term Proposals, Treasury Proposals, and Survey Proposals

Also proposals for Theory Programs, Data Science Software development, and **Archival Programs** to support analysis of calibration, the Director's Discretionary Early Release Science (DD-ERS) data, and the GTO AR-accessible programs

Archival Research for Solar System

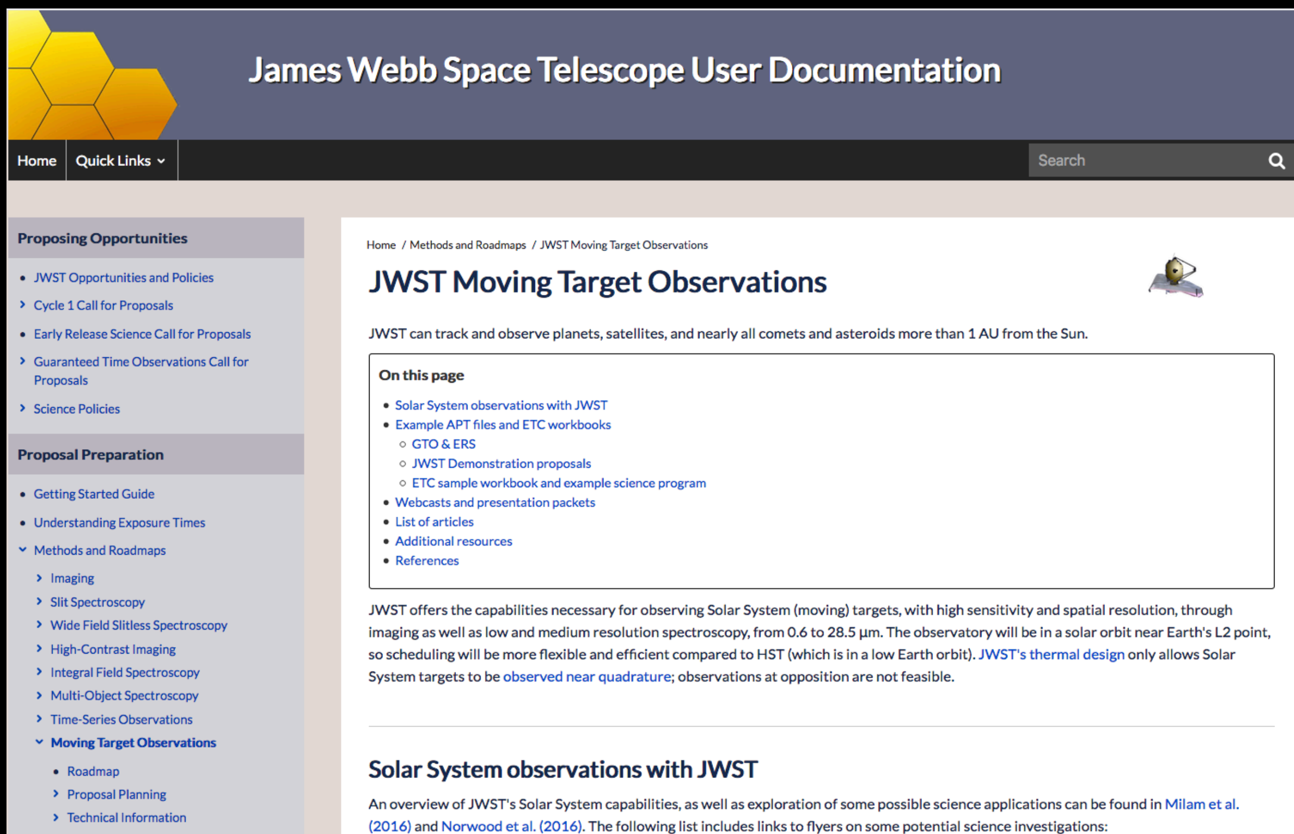
Programs with this icon have components that have no exclusive access period, and can be used as a basis for GO Cycle 1 Archival Research (AR) Proposals.

ID	Program Title	AR?	Principal Investigator	Instrument
1191	Kuiper Belt Science with JWST		John Stansberry (Space Telescope Science Institute)	MIRI NIRSpec
1231	Surface Composition of Mid-sized TNOs: Searching for Ammonia		Aurelie Guilbert-Lepoutre (Institut UTINAM)	NIRSpec
1244	Large Asteroids and Trojan Asteroids	AR	Andrew Rivkin (The Johns Hopkins University Applied Physics Laboratory)	MIRI NIRCam NIRSpec
1245	Near-Earth Objects	AR	Cristina Thomas (Northern Arizona University)	MIRI NIRCam NIRSpec
1246	Jupiter's Great Red Spot	AR	Leigh Fletcher (University of Leicester)	MIRI
1247	Saturn	AR	Leigh Fletcher (University of Leicester)	MIRI NIRCam NIRSpec
1248	Uranus	AR	Leigh Fletcher (University of Leicester)	MIRI NIRSpec
1249	Neptune	AR	Leigh Fletcher (University of Leicester)	MIRI
1250	Probing the Sub-surface Oceans of Europa and Enceladus with JWST	AR	Geronimo Villanueva (NASA Goddard Space Flight Center)	MIRI NIRCam NIRSpec
1251	Titan Climate, Composition and Clouds	AR	Conor Nixon (NASA Goddard Space Flight Center)	MIRI NIRCam NIRSpec
1252	Spectral Mapping of a Comet's Inner Coma	AR	Michael Kelley (University of Maryland)	MIRI NIRCam NIRSpec
1253	ToO Comet	AR	Stefanie Milam (NASA Goddard Space Flight Center)	NIRSpec
1254	TNOs		Alex Parker (Southwest Research Institute)	MIRI NIRSpec
1255	JWST Medium-Deep Fields -- Hammel IDS GTO Program	AR	Stefanie Milam (NASA Goddard Space Flight Center)	NIRCam
1271	ToO TNOs: 'Unveiling the Kuiper Belt by Stellar Occultations'		Pablo Santos-Sanz (Instituto de Astrofisica de Andalucia (IAA))	NIRCam
1272	Kuiper Belt Science with JWST		Dean Hines (Space Telescope Science Institute)	MIRI NIRSpec
1273	Kuiper Belt Science with JWST		Jonathan Lunine (Cornell University)	MIRI NIRSpec
1415	Mars	AR	Geronimo Villanueva (NASA Goddard Space Flight Center)	NIRCam NIRSpec

How to Learn More re JWST & Solar System

How to Learn More re JWST & Solar System

JWST Documentation https://jwst-docs.stsci.edu/



James Webb Space Telescope User Documentation

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Proposing Opportunities

- JWST Opportunities and Policies
- Cycle 1 Call for Proposals
- Early Release Science Call for Proposals
- Guaranteed Time Observations Call for Proposals
- Science Policies

Proposal Preparation

- Getting Started Guide
- Understanding Exposure Times
- Methods and Roadmaps
  - Imaging
  - Slit Spectroscopy
  - Wide Field Slitless Spectroscopy
  - High-Contrast Imaging
  - Integral Field Spectroscopy
  - Multi-Object Spectroscopy
  - Time-Series Observations
  - **Moving Target Observations**
    - Roadmap
    - Proposal Planning
    - Technical Information

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JWST Moving Target Observations

JWST can track and observe planets, satellites, and nearly all comets and asteroids more than 1 AU from the Sun.

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- Solar System observations with JWST
- Example APT files and ETC workbooks
  - GTO & ERS
  - JWST Demonstration proposals
  - ETC sample workbook and example science program
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- Additional resources
- References

JWST offers the capabilities necessary for observing Solar System (moving) targets, with high sensitivity and spatial resolution, through imaging as well as low and medium resolution spectroscopy, from 0.6 to 28.5 µm. The observatory will be in a solar orbit near Earth's L2 point, so scheduling will be more flexible and efficient compared to HST (which is in a low Earth orbit). JWST's thermal design only allows Solar System targets to be observed near quadrature; observations at opposition are not feasible.

Solar System observations with JWST

An overview of JWST's Solar System capabilities, as well as exploration of some possible science applications can be found in Milam et al. (2016) and Norwood et al. (2016). The following list includes links to flyers on some potential science investigations:

How to Learn More re JWST & Solar System

JWST Documentation https://jwst-docs.stsci.edu/

JWST Training Events https://jwst.stsci.edu/events

Applied Filters: planetary ✕ Clear All

15-20 SEP 2019
Science Meetings
JWST at the 51st Annual Division for Planetary Sciences Meeting (Joint with EPSC)
The Joint EPSC-DPS Meeting covers a broad area of science topics related to planetary science and planetary missions. It will take place a few months before the anticipated release for the JWST Cycle...
Read More >

21-26 OCT 2018
Science Meetings
JWST at the 50th Annual Division for Planetary Sciences Meeting
The James Webb Space Telescope will be prominently supported during the upcoming meeting of the AAS Division of Planetary Sciences, which is going to be held in Knoxville, TN. The meeting will include: JWST...
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15-20 OCT 2017
Science Meetings
JWST at the 49th Annual Division for Planetary Sciences Meeting
The James Webb Space Telescope will be prominently supported during the upcoming meeting of the AAS Division of Planetary Sciences, which is going to be held at the Utah Valley Convention Center in Provo,...
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16-21 OCT 2016
Science Meetings
JWST at the 48th Annual Division for Planetary Sciences Meeting (Joint with EPSC)
The James Webb Space Telescope will be prominently supported during the upcoming meeting of the AAS Division of Planetary Sciences, which is going to be held at the Pasadena Convention Center, California....
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8-13 NOV 2015
Science Meetings
JWST at the 47th Annual Division for Planetary Sciences Meeting
The JWST team organized and participated in multiple events to inform the planetary science community on JWST capabilities for Solar System and Exoplanet research. This included a Town Hall meeting and...
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9-14 NOV 2014
Science Meetings
JWST at the 46th Annual Division for Planetary Sciences Meeting
The JWST team organized a workshop on potential science investigations with JWST.
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How to Learn More re JWST & Solar System

JWST Documentation https://jwst-docs.stsci.edu/

JWST Training Events https://jwst.stsci.edu/events

PASP articles (Jan 2016, Vol. 128,No. 959) https://tinyurl.com/y7q6kfra

Special Issue: Innovative Solar System Science with the James Webb Space Telescope

The *James Webb Space Telescope*'s Plan for Operations and Instrument Capabilities for Observations in the Solar System — 018001
Stefanie N. Milam, John A. Stansberry, George Sonneborn, and Cristina Thomas
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Observing Near-Earth Objects with the *James Webb Space Telescope* — 018002
Cristina A. Thomas, Paul Abell, Julie Castillo-Rogez, Nicholas Moskovitz, Michael Mueller, Vishnu Reddy, Andrew Rivkin, Erin Ryan, and John Stansberry
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Asteroids and the *James Webb Space Telescope* — 018003
Andrew S. Rivkin, Franck Marchis, John A. Stansberry, Driss Takir, Cristina Thomas, and the *JWST* Asteroids Focus Group
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Unique Spectroscopy and Imaging of Mars with the *James Webb Space Telescope* — 018004
Gerónimo L. Villanueva, Francesca Altieri, R. Todd Clancy, Therese Encrenaz, Thierry Fouchet, Paul Hartogh, Emmanuel Lellouch, Miguel A. Lopéz-Valverde, Michael J. Mumma, Robert E. Novak, Michael D. Smith, Ann-Carine Vandaele, Michael J. Wolff, Pierre Ferruit, and Stefanie N. Milam
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Giant Planet Observations with the *James Webb Space Telescope* — 018005
James Norwood, Julianne Moses, Leigh N. Fletcher, Glenn Orton, Patrick G. J. Irwin, Sushil Atreya, Kathy Rages, Thibault Cavalié, Agustin Sánchez-Lavega, Ricardo Hueso, and Nancy Chanover
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Observing Outer Planet Satellites (Except Titan) with the *James Webb Space Telescope*: Science Justification and Observational Requirements — 018006
Laszlo Keszthelyi, Will Grundy, John Stansberry, Anand Sivaramakrishnan, Deepashri Thatte, Murthy Gudipati, Constantine Tsang, Alexandra Greenbaum, and Chima McGruder
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Titan Science with the *James Webb Space Telescope* — 018007
Conor A. Nixon, Richard K. Achterberg, Máté Ádámkovics, Bruno Bézard, Gordon L. Bjoraker, Thomas Cornet, Alexander G. Hayes, Emmanuel Lellouch, Mark T. Lemmon, Manuel López-Puertas, Sébastien Rodriguez, Christophe Sotin, Nicholas A. Teanby, Elizabeth P. Turtle, and Robert A. West
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Observing Planetary Rings and Small Satellites with the *James Webb Space Telescope*: Science Justification and Observation Requirements — 018008
Matthew S. Tiscareno, Mark R. Showalter, Richard G. French, Joseph A. Burns, Jeffrey N. Cuzzi, Imke de Pater, Douglas P. Hamilton, Matthew M. Hedman, Philip D. Nicholson, Daniel Tamayo, Anne J. Verbiscer, Stefanie N. Milam, and John A. Stansberry
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Cometary Science with the *James Webb Space Telescope* — 018009
Michael S. P. Kelley, Charles E. Woodward, Dennis Bodewits, Tony L. Farnham, Murthy S. Gudipati, David E. Harker, Dean C. Hines, Matthew M. Knight, Ludmilla Kolokolova, Aigen Li, Imke de Pater, Silvia Protopapa, Ray W. Russell, Michael L. Sitko, and Diane H. Wooden
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Physical Characterization of TNOs with the *James Webb Space Telescope* — 018010
Alex Parker, Noemi Pinilla-Alonso, Pablo Santos-Sanz, John Stansberry, Alvaro Alvarez-Candal, Michele Bannister, Susan Benecchi, Jason Cook, Wesley Fraser, Will Grundy, Aurelie Guilbert, Bill Merline, Arielle Moullet, Michael Mueller, Cathy Olkin, and Darin Ragozzine
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James Webb Space Telescope Observations of Stellar Occultations by Solar System Bodies and Rings — 018011
P. Santos-Sanz, R. G. French, N. Pinilla-Alonso, J. Stansberry, Z-Y. Lin, Z-W. Zhang, E. Vilenius, Th. Müller, J. L. Ortiz, F. Braga-Ribas, A. Bosh, R. Duffard, E. Lellouch, G. Tancredi, L. Young, Stefanie N. Milam, and the *JWST* "Occultations" Focus Group
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JWST GTO Solar System Science Team (thank you!)

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Pablo Santos-Sanz
Occultations

Geronimo Villanueva
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Matt Tiscareno
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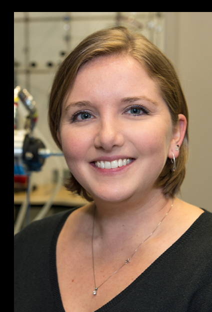
Leigh Fletcher
Atm: Jup, Sat, Ura, & Nep

Alex Parker & John Stansberry
KBOs



Michael Kelley & Stefanie Milam
Comets

Conor Nixon & Jonathan Lunine
Titan

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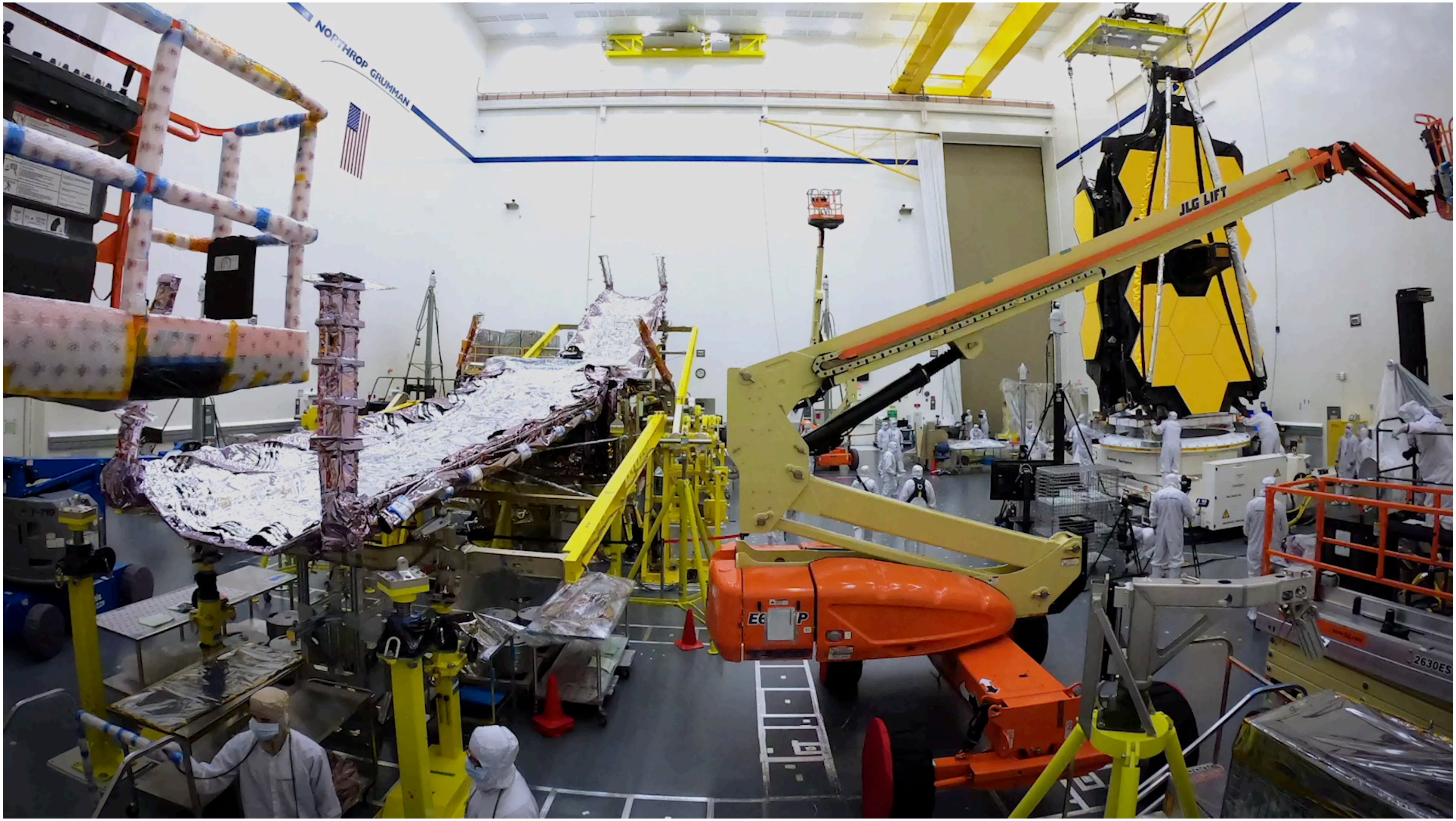
Imke de Pater for ERS details (imke@berkeley.edu)

Thank you. Enjoy the assembly movie! What questions do you have about JWST Solar System?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